EXHIBIT A

REDACTED VERSION – PUBLICLY FILED

United States Patent [19]
Linwood et al.

[11] **Patent Number: 5,027,314**
[45] **Date of Patent: Jun. 25, 1991**

[54] **APPARATUS AND METHOD FOR POSITION REPORTING**

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[73] Assignee: **United Manufacturing Co., Inc.,** New Castle, Del.

[21] Appl. No.: **490,144**

[22] Filed: **Mar. 7, 1990**

Related U.S. Application Data

[63] Continuation of Ser. No. 194,199, May 16, 1988, abandoned, which is a continuation-in-part of Ser. No. 169,285, Mar. 17, 1988, abandoned.

[51] **Int. Cl.**[5] **G06F 1/00;** G08B 23/00; G08B 5/22

[52] **U.S. Cl.** **364/900;** 340/573; 340/825.36

[58] **Field of Search** .... 340/573, 825.36, 825.44, 340/825.49, 825.52, 825.54; 379/38; 364/200 MS File, 900 MS File, 403; 235/375, 385

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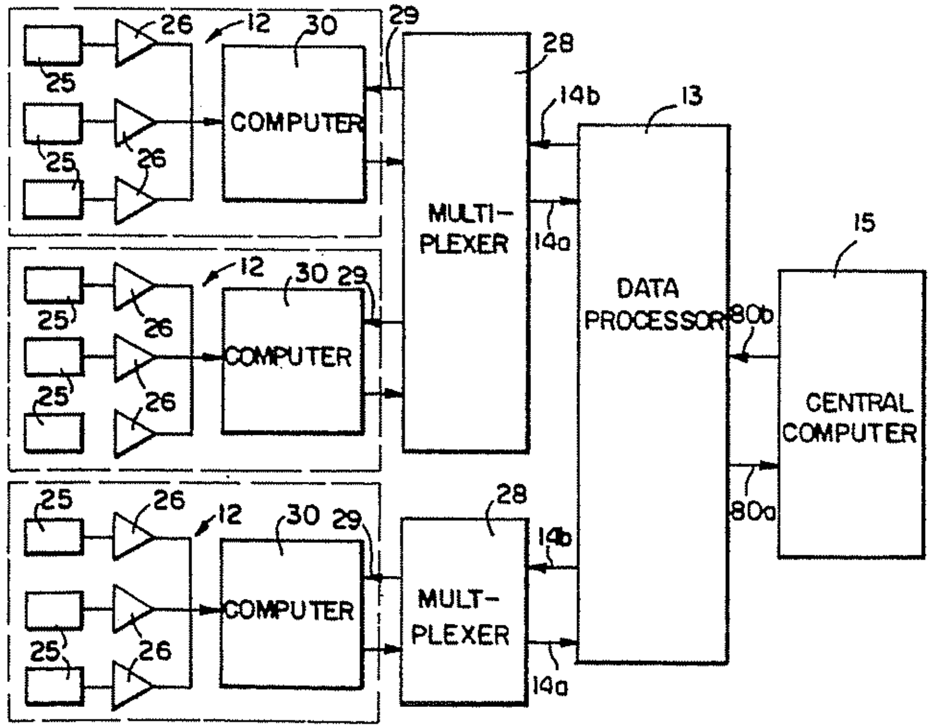
Attorney, Agent, or Firm—Woodcock, Washburn, Kurtz, Mackiewicz & Norris

[57] **ABSTRACT**

A system and method for tracking a number of subjects in a plurality of areas is shown to include a plurality of transmitters, wherein at least one transmitter is associated with each subject, each transmitter transmits a light based signal representative of an identifying code unique to that transmitter, a plurality of receivers, wherein at least one receiver is associated with each area, each receiver converts transmitted light based signals to electrical signals and validates the electrical signal to determine whether such electrical signals are representative of the unique identifying codes associated with the transmitters, and a central processing member, connected to each of the receivers, for recording those electrical signals which are representative of the unique identifying codes for recording the receiver which determined that such electrical signals are representative of the unique identifying codes associated with the transmitters and for determining in which area the transmitter is actually located.

12 Claims, 5 Drawing Sheets



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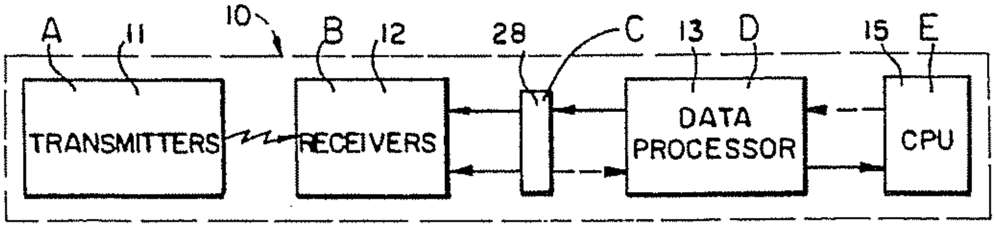


FIG. 1

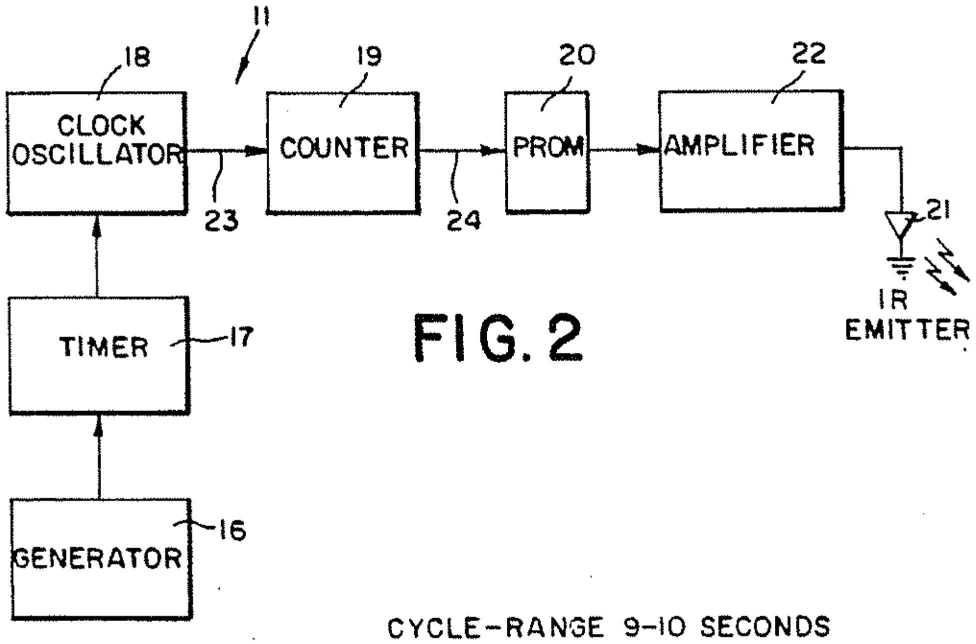


FIG. 2

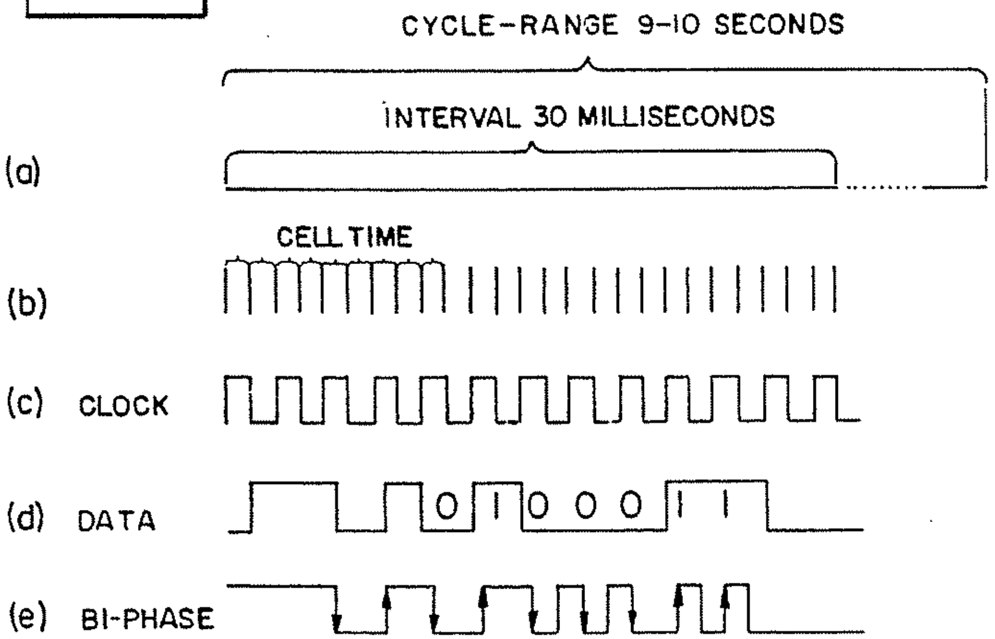


FIG. 3

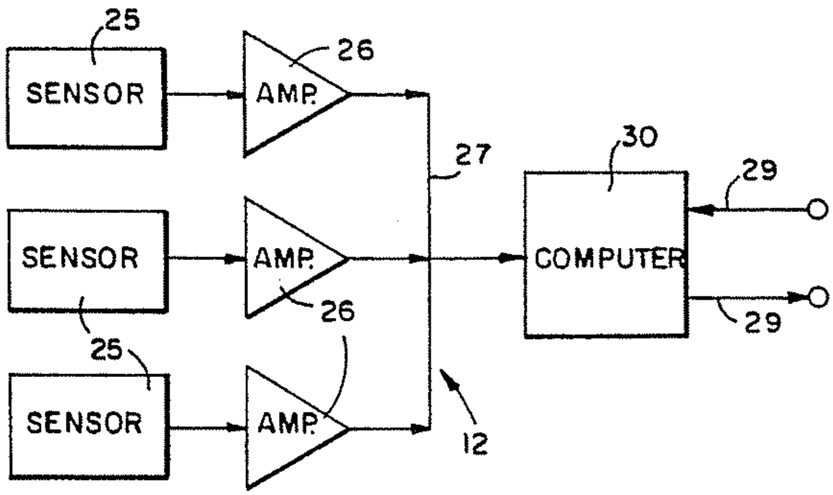

25
SENSOR
26
AMP.
27
30
29
SENSOR
AMP.
COMPUTER
26
29
25
SENSOR
AMP.
12

FIG. 4

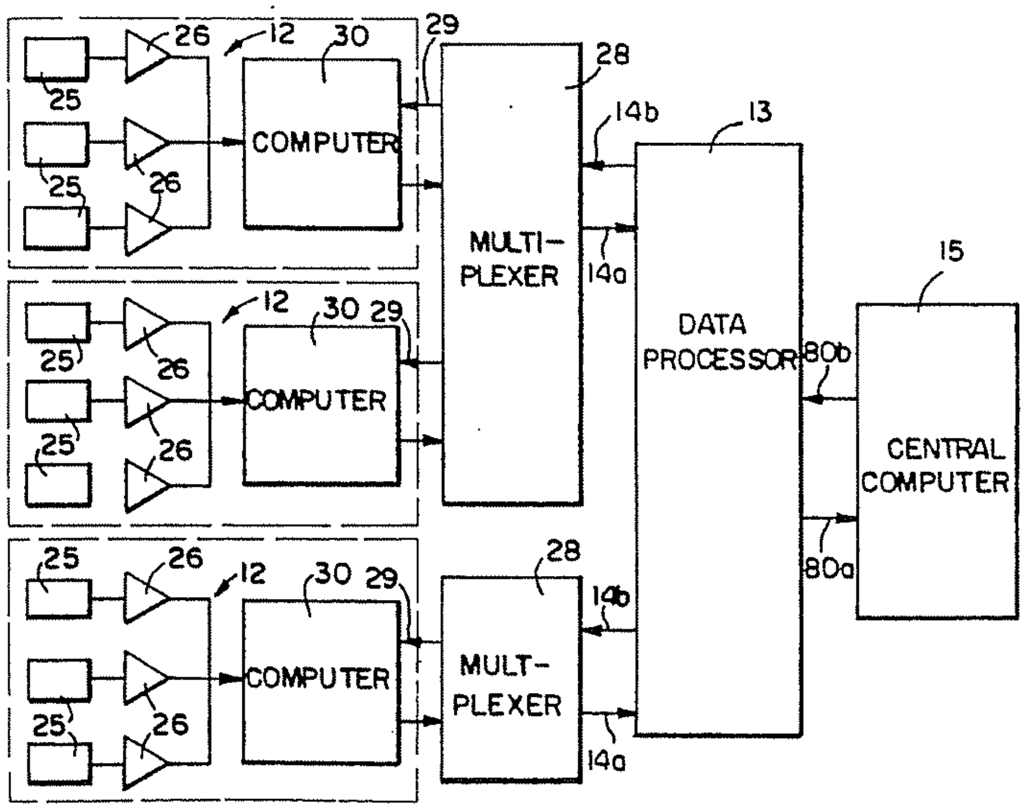

26
12
30
29
28
25
COMPUTER
14b
13
25
26
MULTI-PLEXER
14a
15
12
30 29
DATA PROCESSOR
80b
25
26
COMPUTER
25
26
CENTRAL COMPUTER
25
26
12
30 29
28
80a
14b
COMPUTER
MULT-PLEXER
25
26
14a

FIG. 5

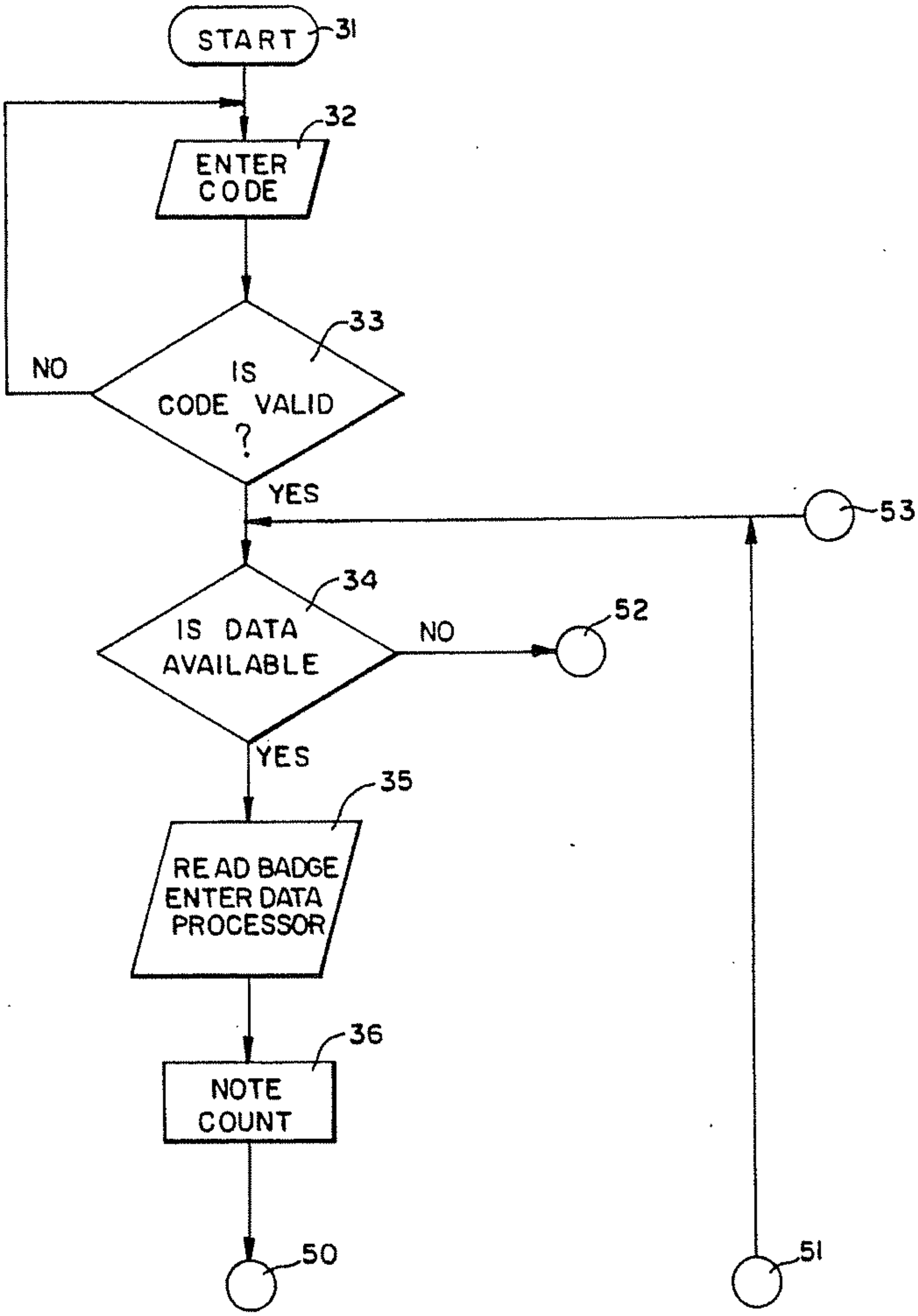
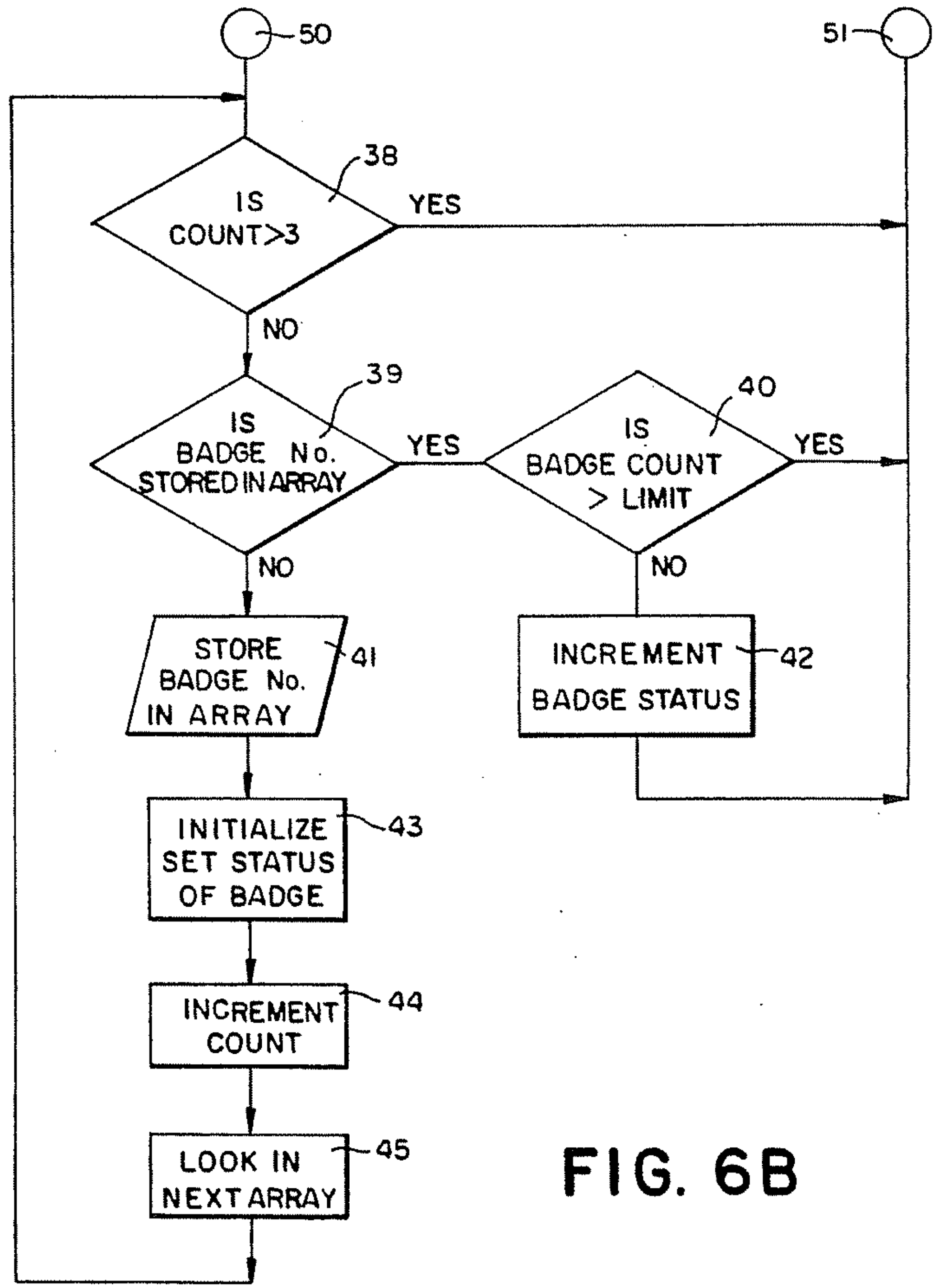

START
31
32
ENTER CODE
33
IS CODE VALID ?
NO
YES
53
34
IS DATA AVAILABLE
NO
52
YES
35
READ BADGE ENTER DATA PROCESSOR
36
NOTE COUNT
50
51

FIG. 6A



50
51
38
IS COUNT>3
YES
NO
39
IS BADGE No. STORED IN ARRAY
YES
40
IS BADGE COUNT > LIMIT
YES
NO
NO
STORE BADGE No. IN ARRAY
41
INCREMENT BADGE STATUS
42
INITIALIZE SET STATUS OF BADGE
43
INCREMENT COUNT
44
LOOK IN NEXT ARRAY
45

FIG. 6B

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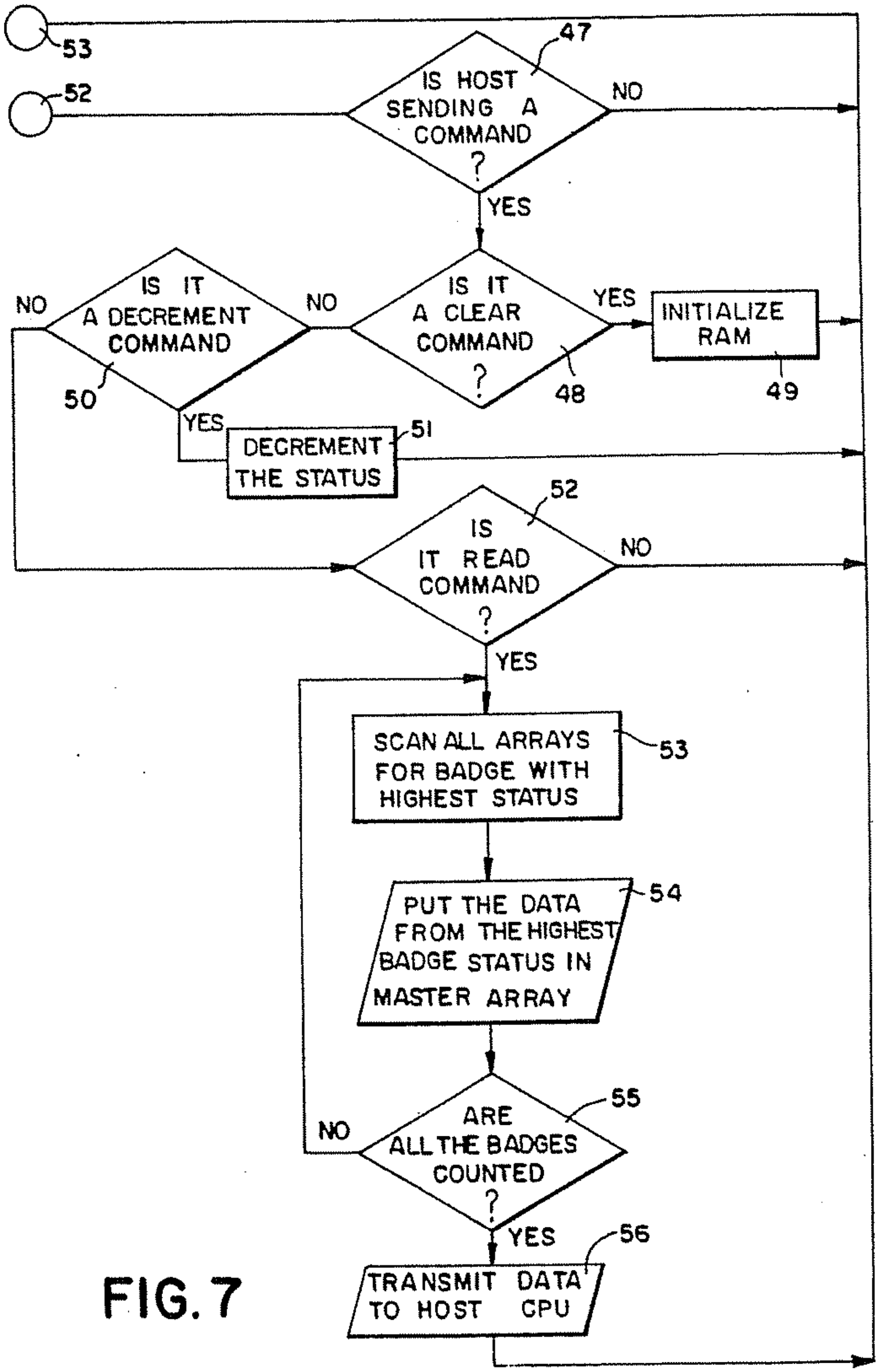

FIG. 7

APPARATUS AND METHOD FOR POSITION REPORTING

This is a continuation of application Ser. No. 07/194,199, filed May 16, 1988, now abandoned, which was a continuation-in-part of applicaton Ser. No. 07/169,285, filed Mar. 17, 1988, now abandoned.

Reference is made to applicants' copending application entitled Apparatus and Method for Varying the Timing of a Control System bearing Ser. No 169,382, filed on Mar. 17, 1988.

The present invention relates to a tracking system for identifying the position of independent subject within designated areas or zones, and is of particular application in remote monitoring and identification of independent subjects within several designated areas of a larger structure and further to tracking systems which accumulate and process the information in a centralized processor.

BACKGROUND OF THE INVENTION

Systems are available for determining the locations of various persons within a multi-area structure. Systems are proposed in which portable transmitters emit coded signals in predetermined intervals to a central receiving station so as to identify the sending portable transmitter. These systems have certain drawbacks and deficiencies, such as requiring a transmission to the portable unit from the receiving station. Also they are complicated and require cumbersome apparatus.

OBJECTS

It is an object of the present invention to provide a system which can track several subjects, such as people, within several areas, such as rooms, within a large structure all at the same time by independent transmission o signals but without interference between the various tracking signals.

It is an object to provide a system in which a plurality of personal transmitters are constantly monitored and identified by transmission to a central processor where the data is used for tasks.

It is a further object to identify the location of individuals by a simple transmitter carried by each individual, which issues independently and without physical restraint a characteristic and coded identifying signal.

Still another object is the independent transmission of a plurality of distinctively characteristic signals for reception within a receiver network by adapting the timing of the various transmissions.

A still further object is the processing of data on identified independent subjects so as to accumulate information about the subjects in a centralized processor for further processing.

SUMMARY OF THE INVENTION

This is an identification system employing infrared radiation for communication within the system. The communication means are a plurality of individually independent transmitters each issuing a distinctive signal in infrared (IR) radiation. An IR transmitter is described in a copending U.S. application. One or more of these IR transmitters are associated with subjects which are movably positioned in one or more monitored areas or zones. It is a feature of the present system that simultaneous multiple transmissions are possible so that the single system can process the information from several locations and formulate it into a single serial data stream in a central processing unit.

Specifically, an identification means is provided for communication from one or more transmitters associated within a system and movably positioned with respect to each other. It is a feature of the present system that multiple transmissions are possible from a plurality of transmitters so that the single system can process the information from several transmitters.

The system is comprised of a central processing unit, a data processor, which feeds to the CPU serial data on one or more subjects. The data on the subjects originates in IR transmitters, for example as a badge carried on the person and from a location remote to CPU and processor. The transmitter has a clock producing pulses which time the sequencing of pulses to produce a characteristic binary number issued from a light emitting diode in infrared radiation for transmission to a fixed sensor. The sensor on receiving the radiation converts it to electrical signals of ones and zeros and processes the data in a processing unit to identify and validate the characteristic binary number as valid and attributable to a designated transmitter.

The characteristic binary numbers are sent to the central processing unit through the data processor which formulates the bits for processing of the information in the CPU.

In the system of the present invention the uniquely distinctive binary coded characters are transmitted from individually independent portable transmitters by IR radiation to one or more receivers in a receiver network. Data processing means in the receiver network identifies and validates the received binary coded character by comparison with stored reference data. The data from the plurality of transmitters is processed through the data processors and all of the data from the individual transmitters is stored together in an array in a main central processing unit. The accumulated data in the main CPU is available for further processing such as identification of the location of the individual transmitters, statistical analysis and print-outs.

Thus this system provides a plurality of individually independent and therefore autonomous portable transmitters capable of readily changing position within a plurality of areas each of which emits a unique code and the plurality of transmissions are processed after validation and stored together in an array from which accumulation the coded data in available for use in many tasks of computations.

BRIEF DESCRIPTION OF THE DRAWINGS

The principles and above mentioned advantages and objects of the present invention will be better understood upon reading of the following description together with the accompanying drawings in which:

FIG. 1 is a functional block diagram of the system of the present invention;

FIG. 2 is a functional block diagram of a transmitter of the system shown in FIG. 1 according to the present invention;

FIG. 3 is a timing diagram with graphs showing the cycle of operation and the transmission intervals of the bi-phase method for data formation and graphs of the relevant functions in this method;

FIG. 4 is a functional block diagram of a receiver of the system shown in FIG. 1 according to the present invention; and

FIG. 5 is a functional block diagram of a plurality of receiver stations and data processors and a central processing unit of the system of FIG. 1 according to this invention;

FIGS. 6A, 6B and 7 are flow charts diagramming an operation of the system.

DEFINITIONS

The following are definitions of terms as used herein;

comparator—a unit that compares two binary numbers telling whether the numbers are equal, one-greater-than-the-other or visaversa.

counter—a special kind of register made up of flip-flop circuits with one input and usually an output from each flip-flip, which counts pulses arriving at the input and stores the total count in a certain code (usually binary numbers).

clock input—an input terminal on a unit typically used for receiving a timing control-clock signal, but used in some applications for a control signal or even data.

programmable—a circuit which can be set with a fixed program.

cycle—an interval of space or time in which one set of events or phenomena is completed.

code—a set of meanings assigned to groups of bits made up of binary representations or binary states provided by a sequence of high and low voltage areas.

character—symbol used as part of organization, control or representation of data.

Binary number—number using base 2 and consisting of the digits 0 and 1.

bit—a 0 or a 1.

Clock—a circuit that generates a series of evenly spaced pulses and in a microprocessor causes the microprocessor to proceed from one step to the next in executing instructions.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring first to FIG. 1, a system 10 of the present invention is illustrated with a block A representing two or more transmitter assemblies 11, a block B representing at least one receiver assembly 12, a block C representing one or more multiplexers 28 at least one data processor stage 13 represented by block D which is connected by lines 80*a* and 80*b* to a central processing unit 15 represented by block E, hereinafter referred to as CPU. Stated briefly, in an arrangement of these parts the transmitters 11 are individually independent and in a portable form, such as a badge, and are associated when in use primarily with subjects. One or more receivers 12 are each located in a designated area or zone so that within this zone one or more transmitters from the transmitter stage and their associated subjects within the transmission range are identified by the operation of the system through the respective receiver 12. The data processor 13 is positioned to receive signals from the receivers 12, and through the interface of the multiplexer 28, sends signals to and receives signals from the CPU 15.

The system 10 provides a network which operates to monitor and identify from a remote location the positioning and location of one or more subjects within one or more designated zones. The transmitters 11 in a preferred embodiment, are badge-size infra-red radiation emitting transmitters. A coded binary number identification signal is produced in each transmitter 11 and is transmitted via infrared radiation to the receiver 12.

FIG. 2 illustrates in a block diagram a typical transmitter assembly 11 of the transmitter stage illustrated in FIG. 1. In one embodiment this is a pocket-sized device passively carried by each individual in the system. The assembly includes a random time variable generator 16 which provides a signal to a timer 17 and which initiates an operation of the transmitter assembly 11.

The initiation of the timer 17 is under the control of the generator 16 and the operation of a voltage level provided by light incident on the assembly. The timing of the occurrence of the signal from the generator 16 is proportional to the incident light. Thus the generator introduces a random time variable resulting from the conventional variations in ambient light in the area. The timer It periodically creates the cycle of pulses of the assembly by sending out a periodic pulse.

The periodic pulse is set to occur at predetermined points in time, such as once every ten seconds, and thus define a cycle. In the present embodiment the timing of the frequency of the pulse can be varied over a range of from once every second to once every 10 seconds with commensurate cycle duration. The timer It actuates a clock oscillator IB in each cycle. The clock oscillator 18 is gated by the pulses from its clock to provide sequencing of a counter 19 associated with a programmable read-only-memory 20, hereinafter referred to as PROM 20. The PROM 20 is programmed with a specific bit pattern which will generate a unique code in a binary number to be transmitted from the transmitter 11. The coded word is in the form of a binary number. The binary character is stored in memory by the program in the PROM 20 to identify the individual transmitter assembly. The PROM 20 is provided with means for easily programming into the PROM 20 an individual and unique code for the respective transmitter assembly 11.

The characteristic binary number of the transmitter unique code is read out of the memory by the sequencing of the memory addresses by the counter. The counter 19 and the PROM 20 when energized by the pulses from the clock oscillator 18 progress through the active interval, 30 milliseconds in the preferred embodiment and then shuts off. The cycle continues for the remainder of the 10 second period. This binary number is transmitted to an infrared emitter 21 through suitable amplifier 22. Emitter 21 which is driven by transistors in the amplifier 2 converts the electrical signals making up the code of the binary numbers into signals of infra-red radiation. This signal emission from the emitter 21 is in a wavelength of from 900 to 10,000 nanometers and an illustrative pulsing frequency is 1.2 milliseconds or 833 pulses/second. The binary numbers making up the binary character are formed by changes in state.

Data is transmitted as a fixed-length stream of binary digits (bits) concatenated to form one or more binary characters. Each bit is weighted according to its position within a character in binary fashion. The bit length is defined by the "bit cell" time which is nominally 1200 microseconds. Data is encoded in a so-called biphase which is defined as follows:

A binary "1" or "logic high" bit is represented by a transition of the signal level from a "0" or logic low voltage level to a "1" or logic high voltage level at the nominal center of a bit cell.

A binary "0" or "low" bit is represented by a transition of the signal level from a "1" or logic high voltage

level to a "0" or logic low voltage level at the nominal center of a bit cell.

The transmitter utilizes an amplitude-shift-keyed modulation technique with a nominal carrier frequency of 38 kilohertz and a data rate of 833 hertz. A logical "0" and a logical "I" are defined by the modulation of the carrier.

In the preferred embodiment, zeroes and ones are transmitted by the radiation from emitter 21 in on-and-off pulses of the infra-red radiation emitting emitter 21.

Referring to FIG. 3 this is a diagram charting graphs of the pulses in an active interval in a transmission cycle of the transmitter 11 assembly which occurs upon actuation of the timer 17 by the operation of a voltage level in the variable time generator !6. It will be readily understood that this active interval as described herein is representative of the actuation in any one of a plurality of transmitter assemblies which are coded with similar cycles of transmission of uniquely coded characters to a common receiver, as explained in greater detail below. The active interval makes up the part of recurring transmission cycle. In this active interval the assembly produces and sends coded characters. With the actuation in the generator 16 of an enabling current and a triggering of the transmission cycle and of the active interval, the timer 12 pulses the clock and these clock pulses are delivered to the oscillator 18. The clock pulses span the active interval. The oscillator 18 initiates and sustains a carrier frequency delivered. These clock pulses are delivered from the oscillator 1B to the counter 19 on line 23. In the present embodiment a suitable carrier frequency is 38 Kc. The counter 19 provides an output in the active interval over address lines 24 to the PRO 15.

The signals from the counter 19 sequence the addresses of the PROM 20 to read out the data stored in the addresses by the programming of the PROM 20. A carrier frequency is provided in the PROM 20 for providing the data carrying bits. Each pulse from counter 19 is related to modulation of the carrier frequency. As noted above, the data is ones and zeroes as encoded by transitions. The data in the addresses is written out by transitions of signal levels from logic high to logic low or vice versa.

The infrared radiation transmitter from the transmitters 11 is received by sensors 25 in the receiver assembly 12 as shown in FIG. 4. According to one aspect of invention the receiver 12 has several sensors 25. As illustrated in FIG. 4 the receiver 12 has three sensors 25 each connected thru amplifiers 26 into a bus 27 which connects to computer 30. Typically one receiver 12 service and receive transmissions from a plurality of transmitters 11 in a designated zone. Computer 30 decodes the binary numbered code output of amplifiers 26 and validates the code by comparison with information stored in the computer 30 memory.

The receiver assembly 12 by operation of the program in the computer 30 receives, synchronizes and decodes the transmitted data from each of the transmitters 12 in the designated area. The processed data is relayed to the data processor 13, shown in FIG. 5.

The data is stored in the memory of the main computer 15 until software routines call for the data to be utilized in subsequent operations.

As shown in FIG. 5, sensors 25 detect infra-red signals within a given frequency band for such radiation and convert the infrared radiation into an electrical signal. As will be understood, the electrical signal represents the coded binary number transmitted by one of the transmitters 11. Each amplifier 26 amplifies electrical signals and the computer 30 converts the encoded bit stream to a binary non-return-to zero bit stream and also provides synchronizing clock signal.

The computer 30 sends a signal 2 data processor 13 on line 38 indicating a binary number identifying code for transmission. The processor 13 returns a clock pulse on line 29 to the computer 30. The computer 30 then sends the converted serial data stream through multiplexer 28 to the processor 13, as shown in FIG. 5.

The data processor 13 accepts serial data streams from a plurality of receivers 12. The multiple receiver data streams are processed in the processor 13. For example, the codes can be validated again by comparison with information programmed into the computer memory. The multiple receiver data stream are combined into a single standard data stream so as to be compatible with processing in the CPU 15. This data stream is transmitted to the CPU IS on line 27.

In FIG. 5 a functional block diagram illustrates a representative system according to the present invention in which three receiver assemblies 12 are defined by broken lines. Each of the three assemblies 12 contains sensors 25 and amplifiers 26 connected to its respective computer 30. Each receiver 12 is connected to a multiplexer 28 by lines 29*a* and 29*b* which are illustrative of the two way transmission between receivers 12 and the processing of the data in the data processors 13 and the host CPU 15. The multiplexers 28 provide the interface between the receivers 12 and the data processor 13. It will be readily understood that the multiple receivers 12 illustrated in FIG. 5 are representative of the variable number of receivers 12 which may be assembled in the system 10 according to the present invention. Further as shown in FIG. 5 one or more receivers 12 may be connected to one or more multiplexers 28 by the respective lines 29*a* and 29*b*. In turn the multiplexer 28 are connected to the data processor 13. As explained in greater detail below under the program of the system 10 the data processor 13 processes the data initially generated at the transmitters 11 and transmitted to the receiver 12.

The data processor 13 handles the data from the receivers 12 passed by means of multiplexers 28. As described above and explained in greater detail below the data processor is connected to the main or host CPU 15 by lines 80*a* and 80*b* for transmitting data to the CPU 15 and receiving commands from the CPU 15.

As shown in FIG. 4, the CPU 15 typically receives data from more than one data processor 13 and accordingly handles a large number of transmitters from one up to several designated zones. In one embodiment the CPU 15 handles from 250 to 300 receiver assemblies and a consequently larger number of transmitters. The CPU 15 can remove false data and can change the validated code data.

In the timing diagram of FIG. 3, the uppermost graph (a) illustrates the cycle of transmission and the active interval within the cycle. The cycle is represented as 10 seconds in length and the active interval 30 milliseconds. The next graph (b) illustrates the individual cell times of 1.2 milliseconds each. Thus in the embodiment the 30 millisecond active interval is made up of 25 cells, which define the bit lengths. The cell times represent the timing in the formulating and transmission of the binary characters.

The graph (c) represents the train of clock pulses which as the diagram of FIG. 3 shows are synchronized with the cell times. Accordingly, in the embodiment of this detailed description, the active interval has 13 pulse separated by 12 spacing interims to equal the 25 cell times of the illustrated active interval. Graph (d) illustrates the bits representing binary character consisting a string of ones and zeroes. Graph (e) illustrates in a graphic manner the charge states of the circuitry in the PROM 20 in accordance with the coded bi-phase data which in turn provide the binary code of the binary characters illustrated in graph (d). The vertical lines carrying arrows represent transitions of signal level. The horizontal lines represent states of voltage level. The upward pointing arrows signify a transition from low voltage level to high voltage level and the downward pointing arrows vice versa; correspondingly the upper horizontal lines in the cell times represent "ones" or "I" and the lower horizontal lines in a cell times represent "zeroes" or "0". The transitions are peculiar to the coded characteristic binary number of the individual Transmitter assembly 11. They are produced by the data read out of the PROM 20 addresses as the counter 19 sequences the data containing addresses in the PROM 20. Thus it is seen that the coded data programmed into the PROM 15 of an individual transmitter 11 is read out to make up the characteristic coded binary numbers of the individual transmitter 11. As described above, these signals suitably amplified are sent out from IR emitter for reception and detection, as in the receiver 12.

This reading out and sending of the infrared signal occurs during the active interval illustrated in graph (a) of FIG. 3. Thus transmission occupies a minor sector of the transmission cycle. The relative greater length of the time of the cycle accommodates variations of the timing of the active interval within the cycle.

Each receiver 12 constantly monitors the output of its sensors 25 in the receiver computer 30 waiting for a transition in voltage level which may indicate the start of a transmission from one of the transmitters in an area monitored by the receiver 12. To identify the initiation of such a transmission the code provides a characteristic bit signal. As illustrated in the data graph (d) of FIG. 3 the first bit is 3 milliseconds long. The computer 30 is programmed to recognize this as identifying the start of the transmission of a coded binary number, which follows as illustrated in graph (d) of FIG. 3. The receiver 12 then reads in the bits from a transmitter 11 which make up the unique binary number.

The computer 30 on receiving the characteristic bits identifies the code number being transmitted. When the coded binary number has been assembled in the computer 30 it is ready for validation by a comparison. The matching code number is read in from the computer memory. In one comparison method the data from the transmitter 11 is read into a register not shown and the data the transmitter 11 is read into a register not shown and the data from memory into a register not shown. After the values are entered a comparison of the values is made by subtraction. If a match of values is indicated the receiver 12 recognizes the transmission as a valid one. The receiver 12 goes thru isolation to report to the main CPU 15 thru the data processor that a value data transmission has been made.

As indicated by the graph of FIG. 3 the clock signal and the data signal ar synchronized. This is achieved by 12 locking on to the transmission.

The identification signal validated by computer 30 is transmitted from the receiver 12 to the data processor 13. The computer of the data processor 13 constantly monitors all receivers 12 connected to it. When any one of the receivers signals that it has an identification signal, i.e., a badge code, the data processor 13 reads that code from the receiver and stores it in RAM memory. All transmissions from receivers are stored together this way in a large array. The data processor 13 is also continuously watching for a signal from the CPU 15 which will indicate a request for the data which has been accumulated.

The main CPU IS cycles through several different tasks. The only task that is required for system operation is the requesting of data from the data processor 13. When data is requested from the data processing computer, the data processing computer sends the entire array of data back to the main CPU 25. At this point, anything may be done with the data that the use requires.

In the operation of the present invention the accumulation of data relating to a number of subjects is possible. An advantage of the invention is a constant monitoring of a number of transmitters which are positioned both in common areas and in separate areas, and which are portable and not mechanically attached to the receiver but are individually independent.

The operational sequence of the system is illustrated by the flow sheet of FIG. 6. The initiation of the operation as represented by the oval 31. The transmitter assemblies Il and the receiver assemblies 12 are energized; this function is indicated diagrammatically by oval 31. The circuitry is now prepared for the transmission and entry of badge numbers associated with the transmitter assemblies 11 to identify the location of subjects. The entry of a badge number by the transmission of a coded binary number code from a transmitter 11 to a receiver is represented in the flow chart by the parallelogram 32.

This actuation of a number code by a transmitter 11 for transmission leads to the determination whether the actuation is of a number code of the system, i.e., validation. This decision point is represented by the diamond 33. The determination is made by the procedures described herein. For example, the characteristic binary number issued from an emitter 21 is converted into electrical signals in the binary of ones and zeroes and the data processed and validated as an authentic binary number by comparison with stored data. It is representative of the multiple actuation and transmissions from the several transmitters 11 of the system, during the monitoring operation.

The negative branch of the diamond 33 carries the identification process back to the actuation of another transmission.

The affirmative branch of the diamond 33 carries the operation to sensing the presence of badge numbers in one or more receivers 12 available by data processor 13. This determination is represented by the diamond 34 where the question "data available" is conducted by the programming of processor 13. The affirmative branch leads to the program reading a badge number from a receiver 12 into the data processor 13 as represented by parallelogram 35. In reference to the identification of one such located badge number its subject and the room in which it is located the program procedure can be summarized briefly.

The program recognizes the last four areas in which the badge number has been located. As to that selected

group of areas the system through the program updates the location of the badge number. The program processes and records each identified and processed badge number within this selected number of areas with the following operations as illustrated by the flow chart of FIGS. 6a and 6b.

Upon the locating of an available data at 34, i.e., badge number in a receiver 12, is read into the data processor, as represented by parallelogram 35. This is followed by a procedure which calls for scanning the four areas for identification and location and/or relocation of the badge number, and its accompanying subject. The next step in the program is noting the count or number of identification of that badge number in the data processor 1 i.e. initializing an array pointer or variable N. This is represented by block 36. The pointer indicates the number of areas in which the badge number has been located and can be referred to as an area count.

The area count having been established, the next step is the determination of whether the area scan associated with the locating procedure for this badge number has inspected more than four areas. This is represented by the diamond 38 in FIG. 6b; note 0 counts as 1.

If the area count is greater than 3 the processing loops back to seeking data from the receiver 12 stage. This means that the scan procedure of the selected group has run its course. If the area count is not greater than 3 the procedure branches to storing the badge number in the array correlated to that area, i.e. the room, in which the badge has been located and identified and for searching other areas. The first step in this procedure is the determination of whether the identified badge number is in the first area. This is for the purpose of determining if the badge number is to be stored in the correlated array of that area. This determination is represented by the diamond 39. An affirmative carries the procedure to the determination of whether the number of identifications of that badge number in that array is within a set limit, of seven for example. This is represented by the diamond 40. If the determination is that less than the limit has been counted, i.e., the badge count for that are is less than a set limit, the procedure branches to block 42, where the badge count is incremented. The steps then proceed to looping back to seeking data from the receivers 12 for entry into the data processor 13.

If the badge count as determined in diamond 40 shows the count of identifications of the specific badge over the limit, then the procedure loops back immediately to the scan for data from the receivers 12.

If the determination at diamond 39 is that the badge number is not in the first of the designated areas then the program stores the badge number in the array for that area at 41, sets the status of the identified badge in the relevant array, i.e., the badge count to one and then increments the count of the areas inspected as represented by block 44. This records in the host CPU IS that one of the four areas has been inspected. Then having failed to initially find that badge number in that inspected area, the scanning procedure calls for looking for the located badge number in the next designated area as represented by the block 45. This leads to looping to the determination whether the locating procedure for this specific badge has inspected more than four areas in the determination of diamond 38 and the procedure described above associated therewith. A negative determination branches to the question as represented by diamond 39. If the count of areas is greater than 3 stated i.e., if four areas have already been inspected, an affirmative results indicating that the scanning step of the group of areas is fulfilled. Then the processing loops back to seeking data from the receiver stage 12.

The negative branch from diamond 38 carries the procedure to inspecting the next designated area and a repetition of the determination in diamond 39 and diamonds 40.

This programmed procedure as outlined above in relation to a badge number identified in one of the monitored areas, i.e. rooms etc. is typical as an example of the tasks performed by the program of the present invention. Thus it will be seen that the program operates to process the identified badge numbers in the monitored areas by first entering the badge number in an address in an array associated with the area where the badge number was identified and then counting and tallying the number of identifications of the badge number in the respective arrays until the limit for the particular badge is attained. Also the program monitors, records and processes in each 10 second cycle the history of each specific badge for the last four areas scanned. When the set limit for locating monitored areas has been reached for all four monitored areas of the sweep, the storing of the badge number is discontinued and in subsequent identification the program loops back through the affirmative branch of diamond 38.

Referring to FIG. 7, when the data processor is not receiving data from the receivers the program branches to check for commands from the main CPU 15. The following steps involve commands from the host CPU 15 which process information on the location of the badges.

The processing identifies commands and executes functions in accordance therewith. FIG. t illustrates such procedures. The first determination is represented by the diamond 47 to which the program branches via the connector 45 with the question, is the CPU 15 sending a command as shown in diamond 47. The negative branch from diamond 47 carries the program back to seeking data from the receivers.

The affirmative branch carries the system to the reception and execution of commands in the program. The next determination is whether there is a CLEAR command as represented by the diamond 48. The affirmative branch from diamond 48 indicating a CLEAR command leads to initializing all the arrays which is a removal or clearing of all data from all the arrays, represented by block 49.

Each array has two halves. One half records the area where the badge is located, the other half keeps track of the count of the identification of the badge.

The negative branch from the diamond 48 indicates that in this time in the procedure the badge is being monitored rather than being stored.

For the purpose of this specific example, in this operation the host CPU is assumed to scan the array every 10 seconds. The command to decrement occurs normally once every 10 cycle. When executed, the command decrements the status of all badges downward. This is represented by block 51.

A negative response in diamond 50 branches to the next determination is there a READ command. This is represented by diamond 52. An affirmative response leads to the function of scanning block 53. all the arrays are scanned for the one having the highest badge status and putting it in a fifth or master array, parallelogram

54. After the master array has been updated the data is transmitted to the host CPU IS as represented by parallelogram 55. Upon completion of the transfer to the host CPU 15 the next determination is whether all of the badges in the system have been check as represented by diamond 56. The negative branches loops back to block 53 and scanning the arrays for the badge with the highest count. The affirmative branch loops to connector 46 and seeking data from the receiver 12.

We claim:

1. A system for tracking a number of subjects in a plurality of areas comprising:

a plurality of transmitters, wherein at least one transmitter is associated with each of said subjects, each of said transmitters comprising transmission means for transmitting a light based signal representative of an identifying code unique to that transmitter;

a plurality of receivers, wherein at least one of said receivers is associated with each of said areas, each of said receivers comprising a converter for converting a transmitted light based signal to an electrical signal and a validation circuit for processing said electrical signal to determine whether said electrical signals are representative of the unique identifying codes associated with said transmitters; and

processor means, connected to each of said receivers, for recording those electrical signals which are representative of said unique identifying codes, for recording the receiver which determined that such electrical signals are representative of the unique identifying codes associated with said transmitters and for determining in which of said areas said transmitters are located, wherein said processor means comprises scanning means for scanning said receivers and accumulating means for accumulating with respect to each transmitter those areas in which receivers have determined that an electrical signal is representative of the unique identifying code associated with that particular transmitter and for accumulating a badge count for each accumulated area, said badge count being representative of the number of times a receiver has determined that an electrical signal is representative of the unique identifying code associated with that particular transmitter.

2. The system of claim 1, wherein said light based signals are infra-red radiation based signal.

3. The system of claim 1, wherein each of said receivers includes at least two converting means for converting transmitted light based signals to electrical signal.

4. The system of claim 1, wherein each of said transmitters is a portable device associated with an individual subject.

5. The system of claim 1 wherein said validation circuit comprises a computer for comparing said electrical signal to a second electrical signal representative of said unique identifying codes.

6. The system of claim 1, wherein said validation circuit comprises a memory for storing said unique identifying codes, and wherein the determination of whether an electrical signal is representative of a unique identifying code associated with said transmitters is achieved by comparing said electrical signal to said unique identifying codes stored in said memory.

7. The system of claim 1, wherein said processor means further comprises comparison means for comparing the accumulated number of areas and said bade counts to respective reference numbers and for generating an indication of such comparisons.

8. The system of claim 1, wherein said processor means further comprises location means for determining the location of said transmitters in relation to the indication from said comparison means.

9. A method for tracking a number of subjects in a plurality of areas in a system wherein at least one transmitter is associated with each of said subjects, each transmitter being capable of transmitting a light based signal representative of an identifying code unique to that transmitter, comprising the steps of:

converting, in a receiver, the transmitted light based signal to an electrical signal and validating said electrical signal to determine whether said electrical signal is representative of the unique identifying codes associated with said transmitter;

recording those electrical signals which are representative of said unique identifying codes;

recording the receiver which determined that such electrical signals are representative of the unique identifying codes associated with said transmitters; and

determining in which of said areas said transmitters are located, wherein the recording the receiver and the determining steps comprise the steps of scanning said receivers and accumulating with respect to each transmitter those areas in which receivers have determined that an electrical signal is representative of the unique identifying code associated with a particular transmitter and accumulating a badge count for each accumulated area, said badge count being representative of the number of times a receiver has determined that an electrical signal is representative of the unique identifying code associated with the particular transmitter.

10. The method of claim 9, wherein the step of validating the electrical signal comprises the step of comparing said electrical signal to a second electrical signal representative of said unique identifying codes.

11. The method of claim 9, further comprising the steps of comparing the accumulated number of areas and said badge counts to respective reference numbers and generating an indication of such comparisons.

12. The system of claim 11, further comprising the step of determining the location of said transmitters in response to the indication of comparisons.

* * * * *

EXHIBIT B

US005572195A

REDACTED VERSION – PUBLICLY FILED

United States Patent [19]

Heller et al.

[11] Patent Number: 5,572,195

[45] Date of Patent: Nov. 5, 1996

[54] SENSORY AND CONTROL SYSTEM FOR LOCAL AREA NETWORKS

[75] Inventors: Alan C. Heller, San Antonio, Tex.; Steven Springmeyer, Bellevue, Wash.; Christopher W. Fox, Englewood, Colo.

[73] Assignee: Precision Tracking FM, Inc., Dallas, Tex.

[21] Appl. No.: 283,832

[22] Filed: Aug. 1, 1994

[51] Int. Cl.[6] H04Q 1/00

[52] U.S. Cl. 340/825.35; 340/825.44; 342/451

[58] Field of Search 340/825.36, 825.49, 340/825.35; 342/450, 451, 463

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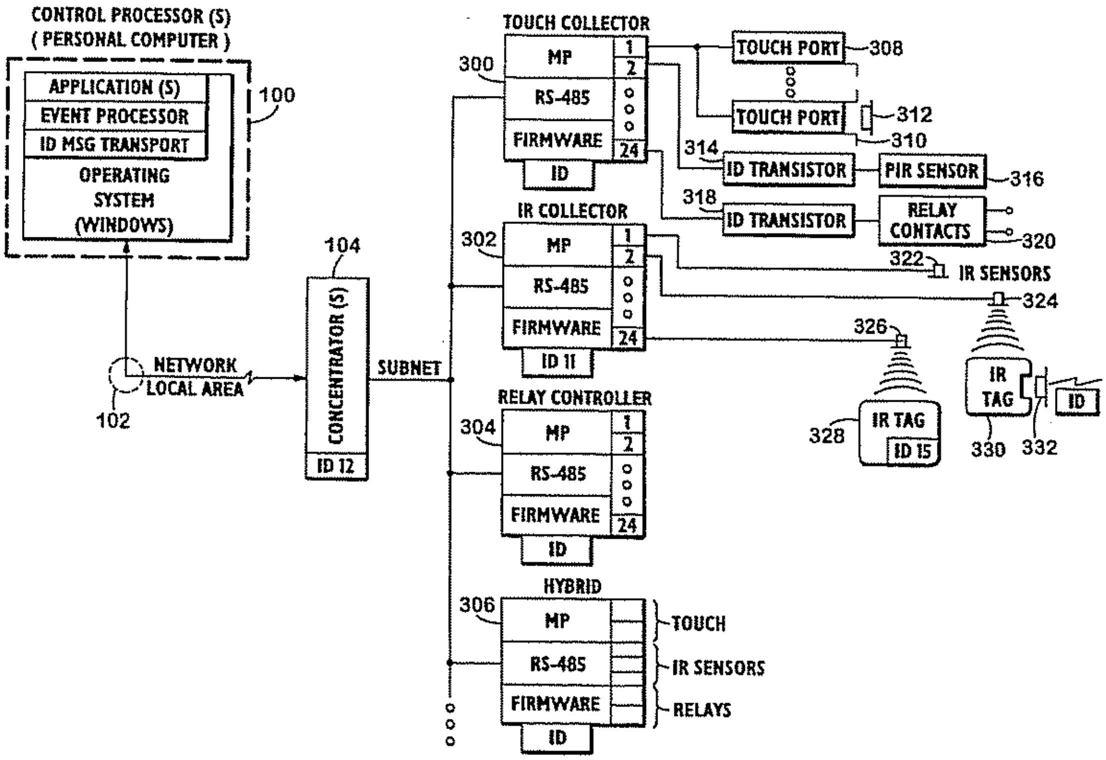
Primary Examiner—Brian Zimmerman
Attorney, Agent, or Firm—Pravel, Hewitt, Kimball & Krieger

[57] ABSTRACT

An object location, control, and tracking system is implemented using an object identifier variable-based protocol such as SNMP. Infrared sensors, touch memory ports, passive infrared sensors, and external device controllers are all accessed using object identifier variables and in this way stimuli events are reported to a computer on the network, and the external devices are controlled responsive to the stimuli.

19 Claims, 9 Drawing Sheets



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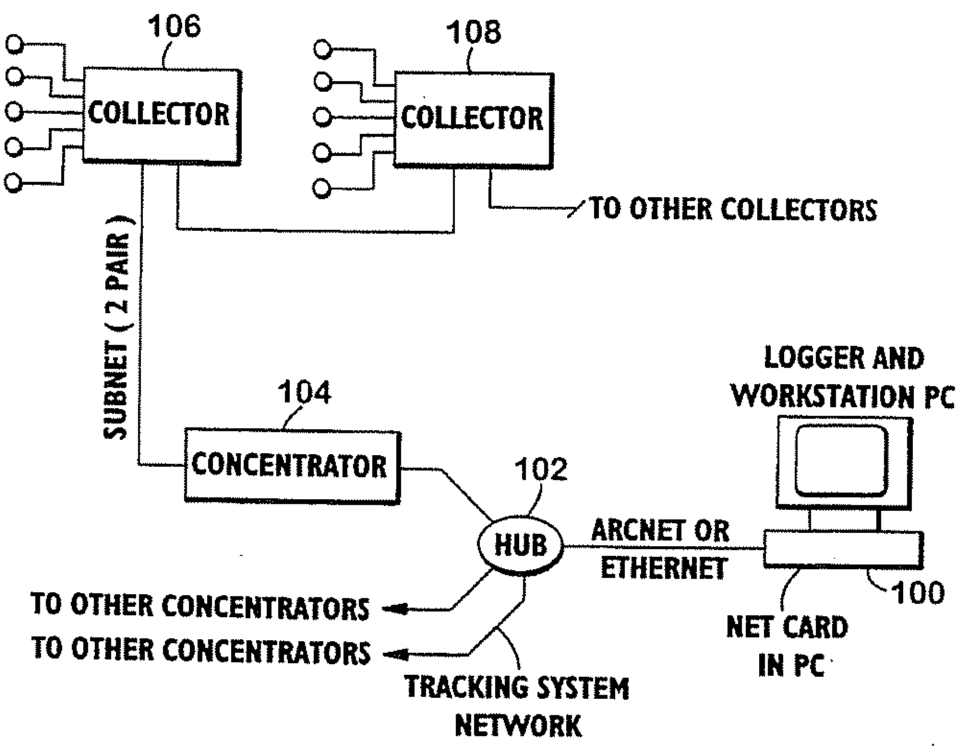
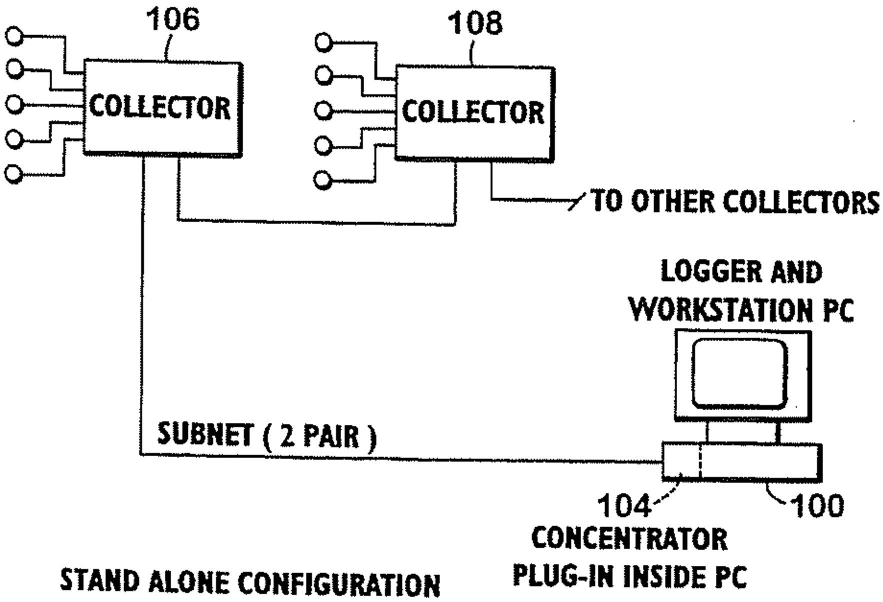


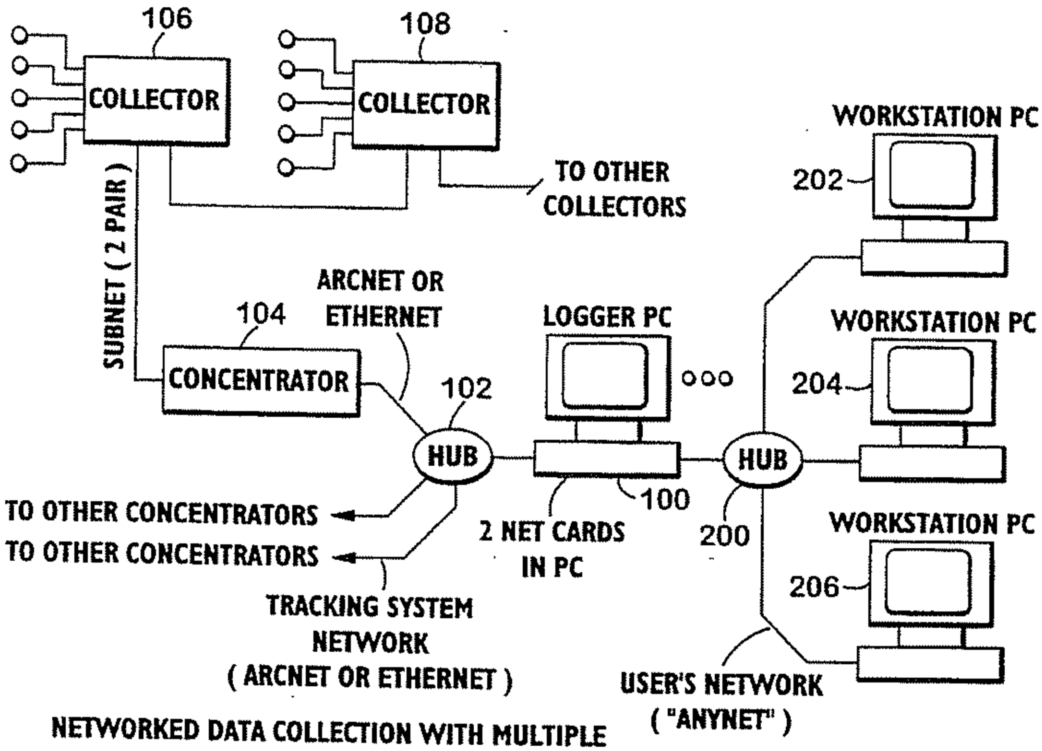
NETWORKED DATA COLLECTION WITH SINGLE WORKSTATION

Fig. 1



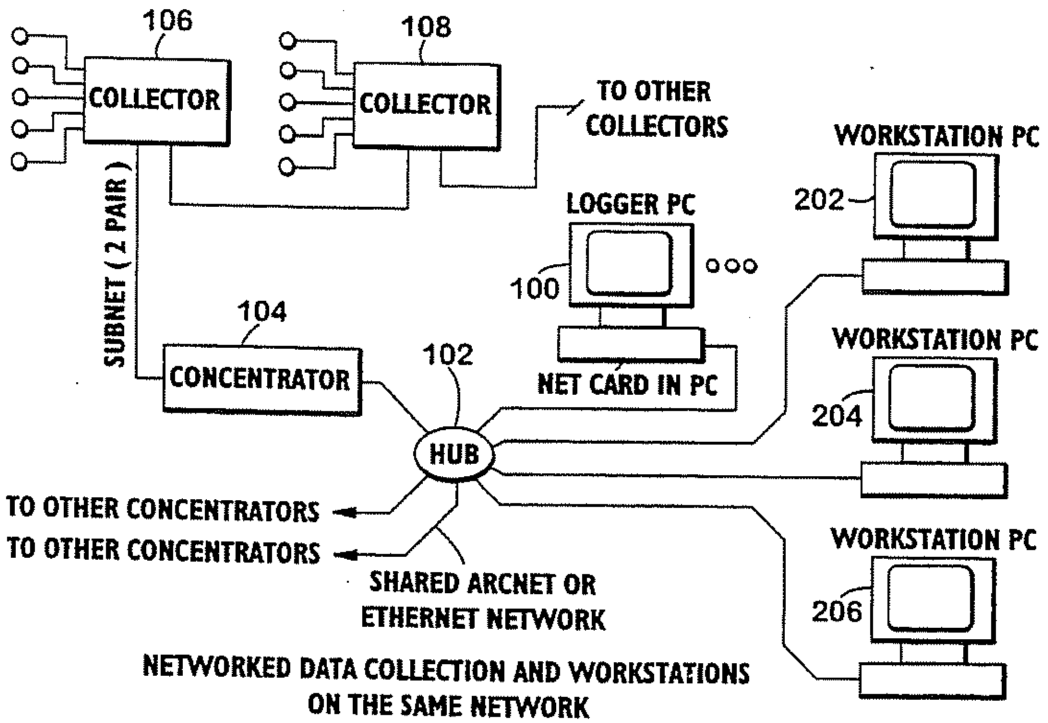
STAND ALONE CONFIGURATION

Fig. 2



NETWORKED DATA COLLECTION WITH MULTIPLE NETWORKED WORKSTATIONS

Fig.3



NETWORKED DATA COLLECTION AND WORKSTATIONS ON THE SAME NETWORK

Fig.4

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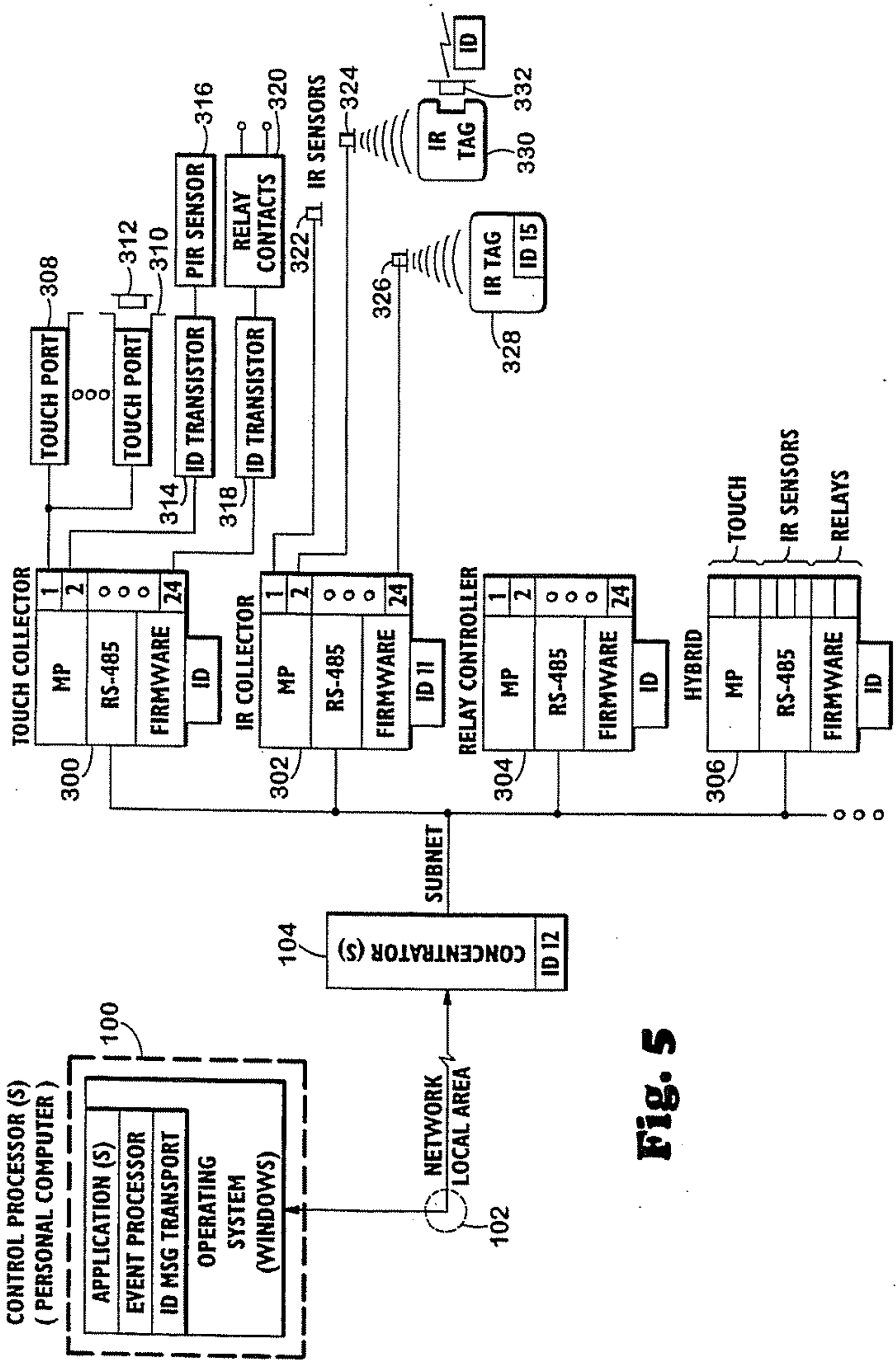

Fig. 5

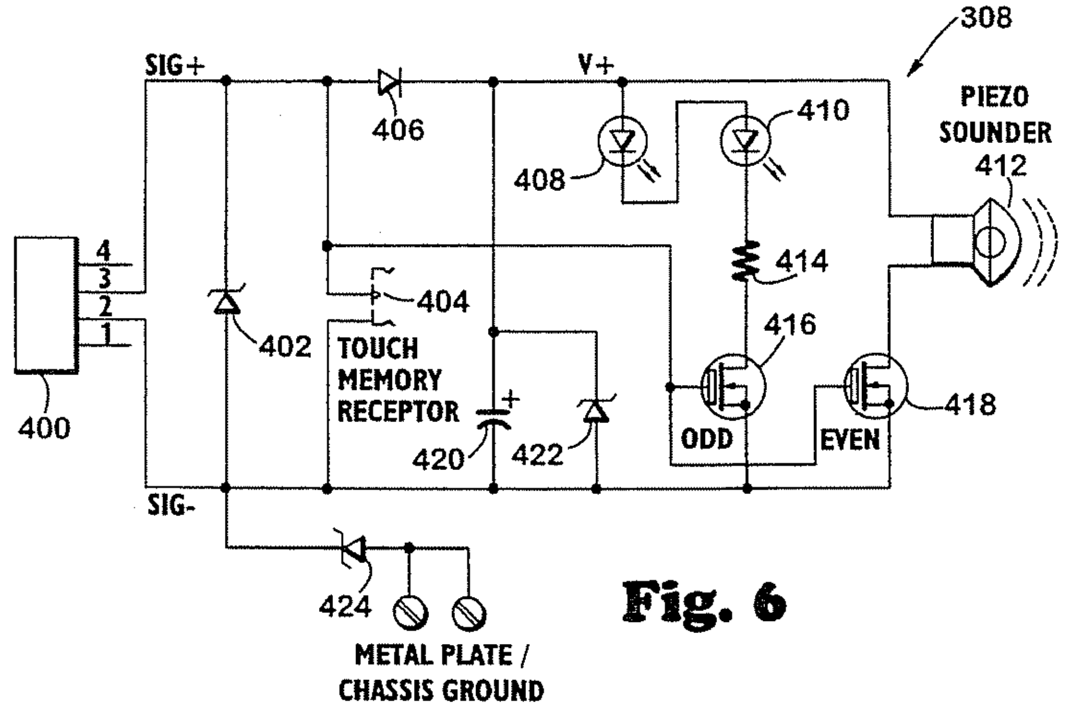

Fig. 6

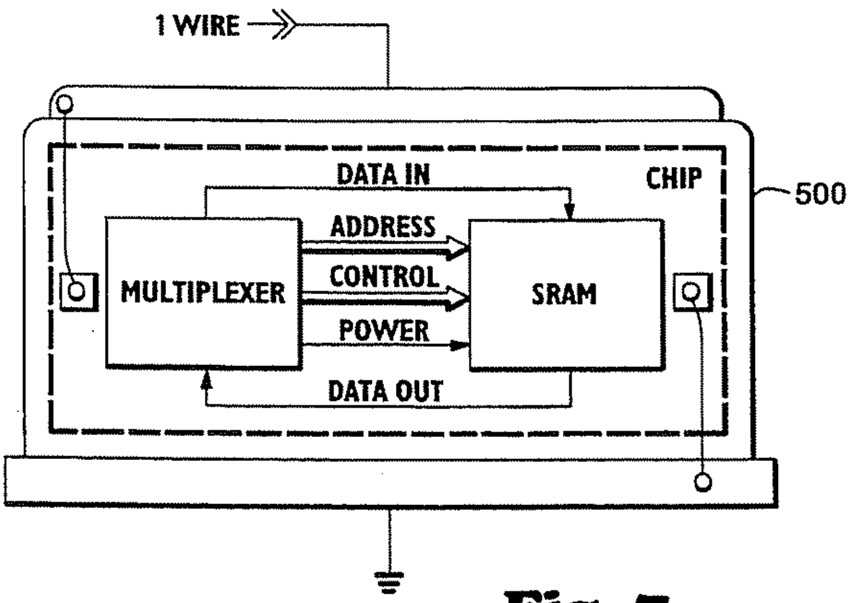

Fig. 7
(PRIOR ART)

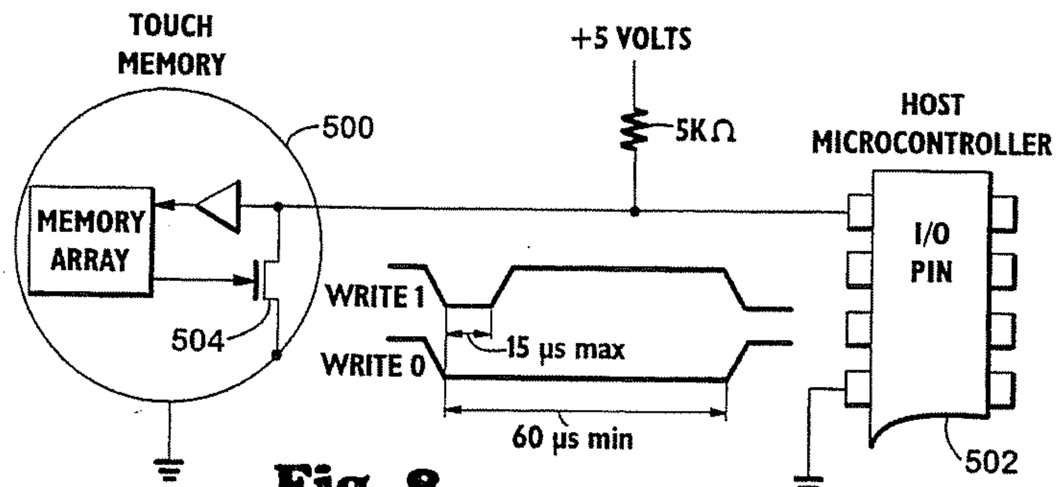

Fig. 8
(PRIOR ART)

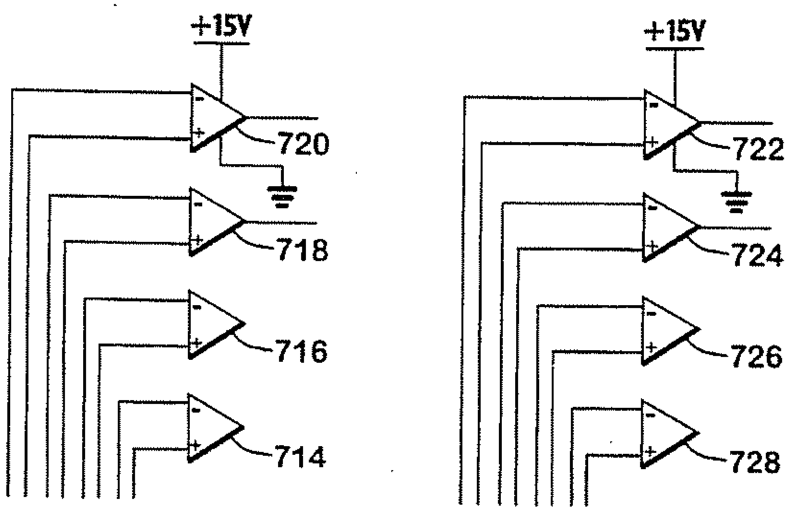

Fig. 10

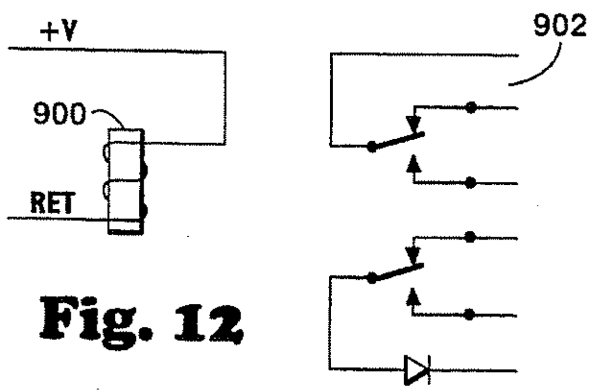

Fig. 12

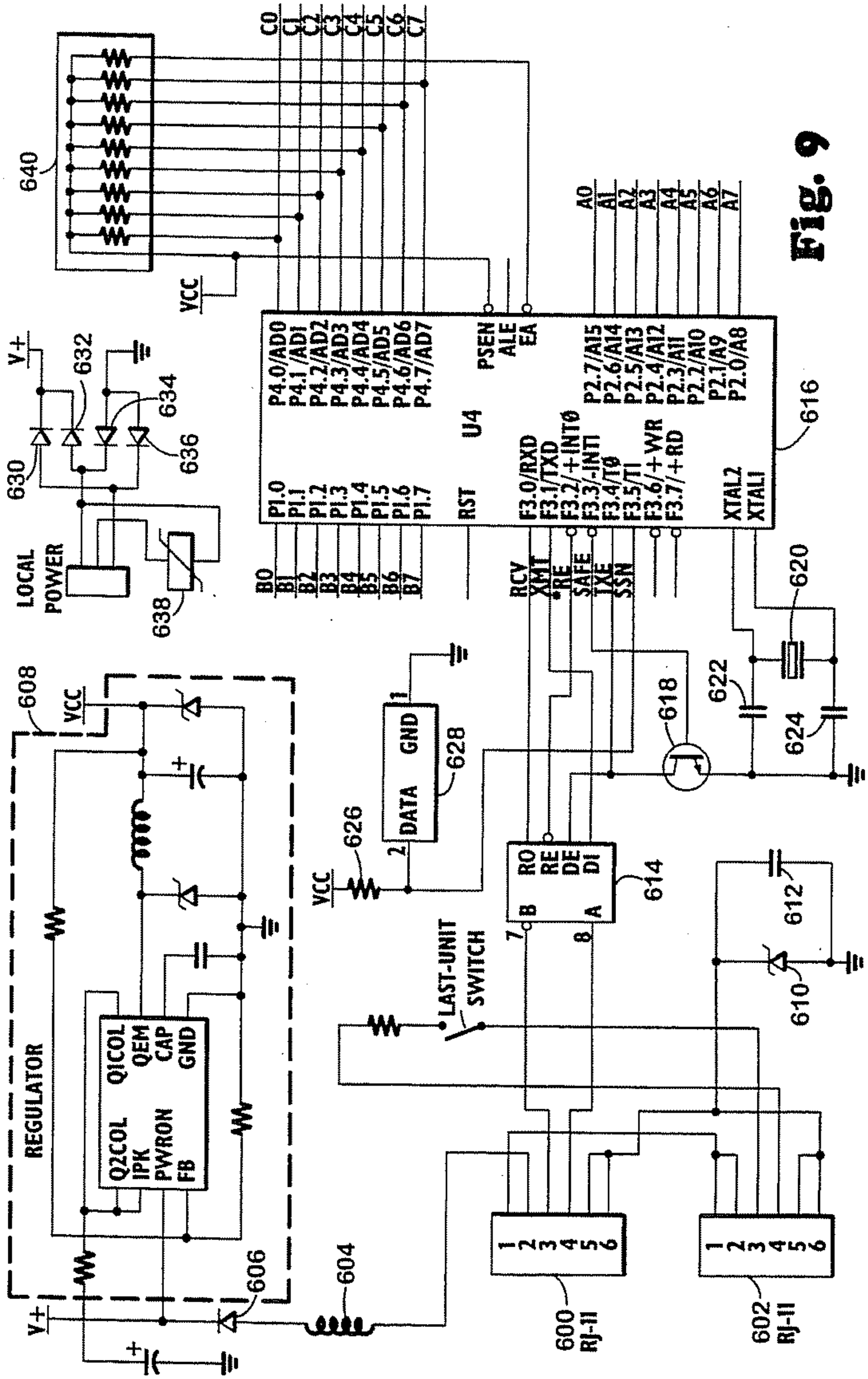
640
VCC
C0
C1
C2
C3
C4
C5
C6
C7
P4.0/AD0
P4.1/AD1
P4.2/AD2
P4.3/AD3
P4.4/AD4
P4.5/AD5
P4.6/AD6
P4.7/AD7
PSEN
ALE
EA
A0
A1
A2
A3
A4
A5
A6
A7
P2.7/A15
P2.6/A14
P2.5/A13
P2.4/A12
P2.3/A11
P2.2/A10
P2.1/A9
P2.0/A8
U4
616
P1.0
P1.1
P1.2
P1.3
P1.4
P1.5
P1.6
P1.7
RST
XTAL2
XTAL1
B0
B1
B2
B3
B4
B5
B6
B7
RCV
XMT
RE
SAFE
TXE
SSN
V+
632
634
636
630
LOCAL POWER
638
620
622
624
618
608
VCC
628
GND
DATA
626
VCC
614
RO
RE
DE
DI
B
A
612
610
LAST-UNIT SWITCH
REGULATOR
Q1COL
QEM
CAP
GND
Q2COL
IPK
PWRON
FB
606
604
V+
600
RJ-11
602
RJ-11

Fig. 9

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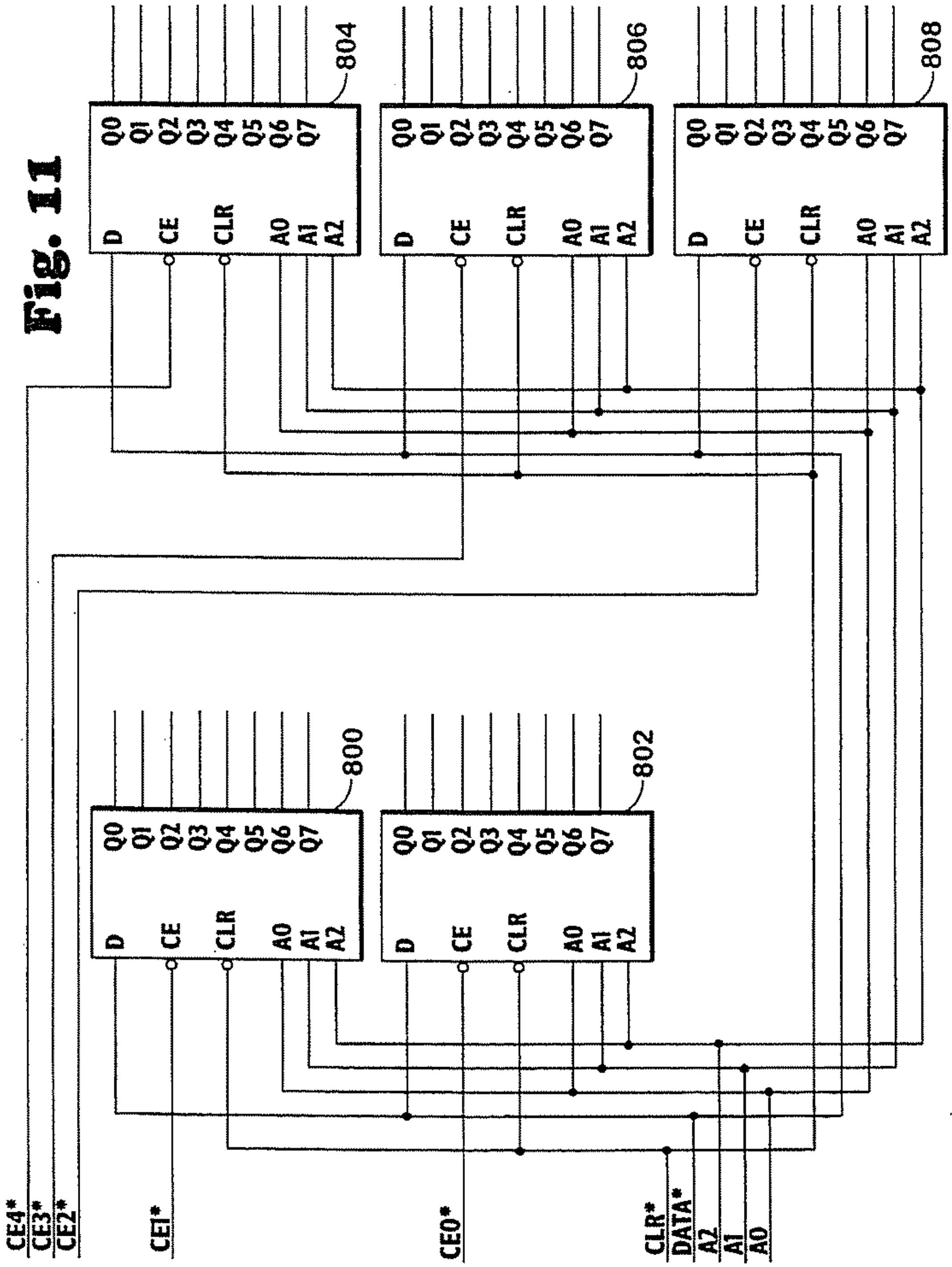
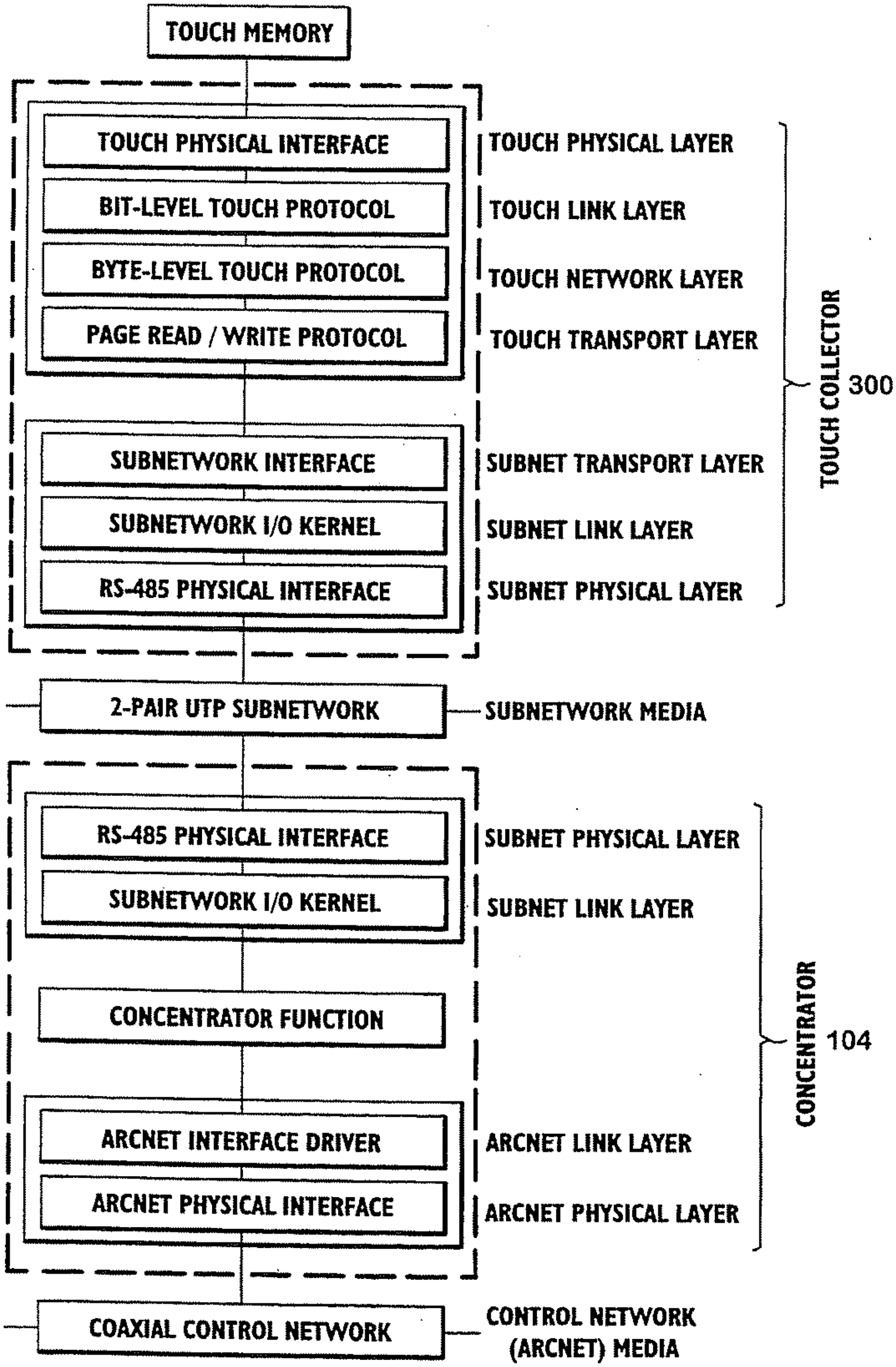


Fig. 11



TOUCH MEMORY
TOUCH PHYSICAL INTERFACE
BIT-LEVEL TOUCH PROTOCOL
BYTE-LEVEL TOUCH PROTOCOL
PAGE READ / WRITE PROTOCOL
TOUCH PHYSICAL LAYER
TOUCH LINK LAYER
TOUCH NETWORK LAYER
TOUCH TRANSPORT LAYER
SUBNETWORK INTERFACE
SUBNETWORK I/O KERNEL
RS-485 PHYSICAL INTERFACE
SUBNET TRANSPORT LAYER
SUBNET LINK LAYER
SUBNET PHYSICAL LAYER
TOUCH COLLECTOR
300
2-PAIR UTP SUBNETWORK
SUBNETWORK MEDIA
RS-485 PHYSICAL INTERFACE
SUBNETWORK I/O KERNEL
SUBNET PHYSICAL LAYER
SUBNET LINK LAYER
CONCENTRATOR FUNCTION
ARCNET INTERFACE DRIVER
ARCNET PHYSICAL INTERFACE
ARCNET LINK LAYER
ARCNET PHYSICAL LAYER
CONCENTRATOR
104
COAXIAL CONTROL NETWORK
CONTROL NETWORK
(ARCNET) MEDIA

Fig. 13A

REDACTED VERSION – PUBLICLY FILED

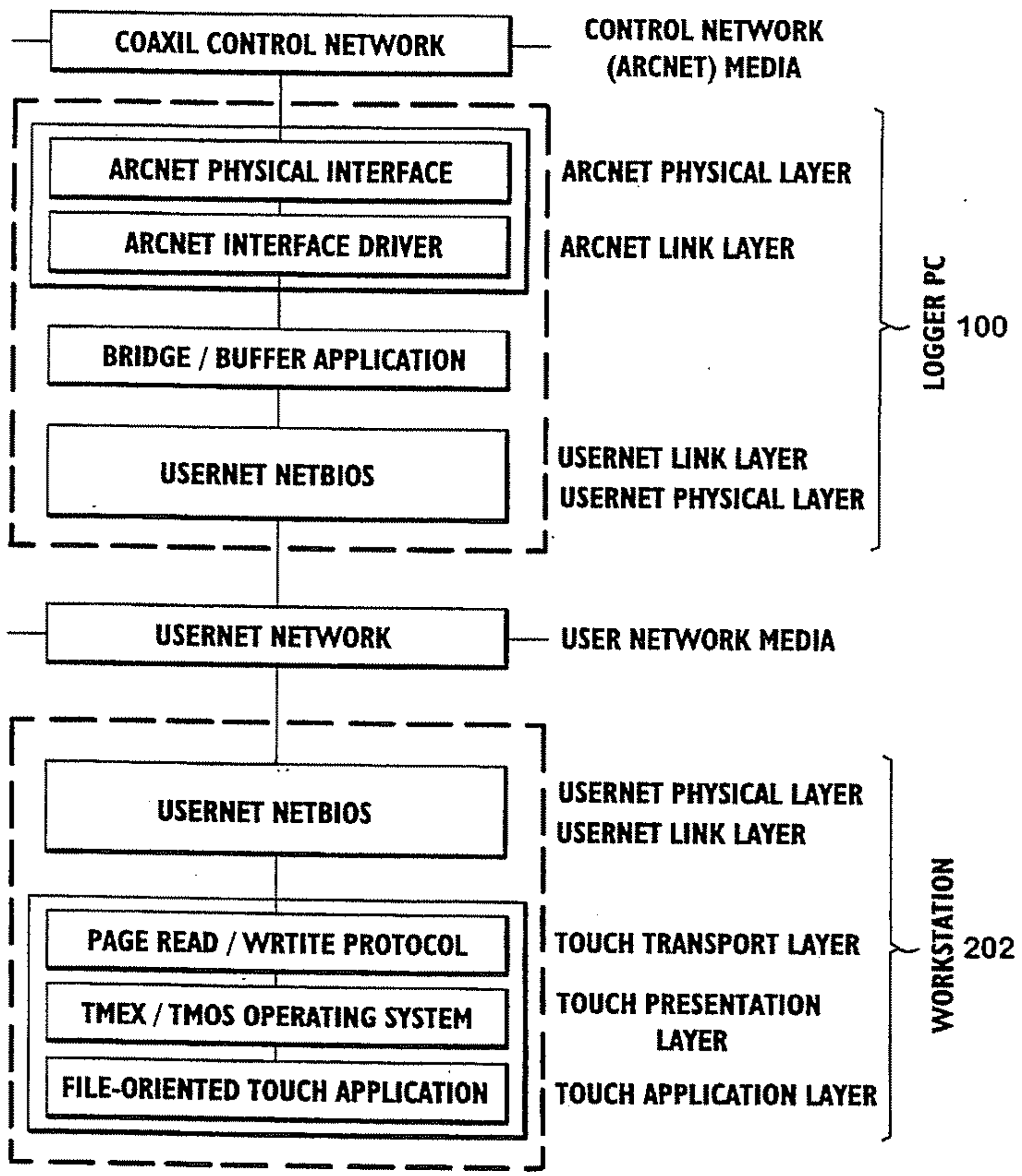


Fig. 13B

SENSORY AND CONTROL SYSTEM FOR LOCAL AREA NETWORKS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to object location and tracking systems, and more specifically, to an object location and tracking system adapted for a local area network and further providing object based communications with and control of physical devices within the environment.

2. Description of the Related Art

Object location and tracking systems are well known to the art. A number of systems have been developed using various techniques, such as infrared, radio frequency, and ultrasonic, for continuously tracking the positions of personnel and objects within a facility.

Infrared techniques have proven especially well-suited to this task. In one particular system, the individuals or objects to be tracked are furnished with infrared transmitters known as "TAGs" containing a unique identification code periodically transmitted to receivers located throughout a facility. Such a system is disclosed in U.S. Pat. No. 4,275,385 to White, which is hereby incorporated by reference. A number of other patents have offered refinements to the techniques in the White patent, such as that disclosed in U.S. Pat. No. 5,119,104 to Heller, issued Jun. 2, 1992, and entitled "Location System Adapted for Use in Multipath Environments", which is hereby incorporated by reference.

But in today's networked environment, such infrared object location and tracking systems can be unwieldy to implement. The microprocessor world has moved steadily and continuously towards network environments, but the various tracking systems previously presented have not adequately addressed the need to smoothly integrate object location and tracking hardware into modern systems. Therefore, it would be greatly desirable to logically and elegantly integrate object location and tracking system hardware into microcomputer network based environments.

Further, while use of infrared TAGs in an object location and tracking system can provide basic functionality in a real-world environment, a number of other elements would be greatly desirable to enhance such systems. Because a TAG can be worn by someone other than its true owner, and because TAGs provide for area identification rather than physical contact identification, it is thus desirable to provide for a more physical manifestation of actual presence.

Further, TAGs only address the detection aspect of an object location and tracking system. It would be greatly desirable to also provide seamlessly integrated facilities for responding to such detection, whether indicated by a TAG or by other presence detection methods.

Finally, in a hardware system implementing all of the above, any reduction in device cost would be greatly desirable.

SUMMARY OF THE INVENTION

A method and apparatus are provided according to the invention for implementing an object tracking and location system using a network that implements object identifier variables. A computer is attached to the network, as well as interface circuitry for interfacing with infrared sensors including passive infrared sensors, touch ports, and external device controllers.

The computer communicates with the interface circuitry using object identifier variables. The object identifier variables identify both the unique identification of the various sensors, touch ports, and external controllers, as well as the unique identities of infrared transmitters that come within the proximity of an infrared sensor, as well as touch memories that are placed within the touch ports.

The computer accesses these devices using object identifier variables and a variable-based protocol, both receiving stimuli from the devices and sending control information to control the external devices.

Using this system, a standard networking protocol based on an object identifier paradigm provides for a device independent solution to problems of interconnecting object location, tracking, and control devices on the network.

BRIEF DESCRIPTION OF THE DRAWINGS

A better understanding of the present invention can be obtained when the following detailed description of the preferred embodiment is considered in conjunction with the following drawings, in which:

FIGS. **1–4** are block diagrams of various systems in which the network environment according to the invention could be implemented;

FIG. **5** is a block diagram showing further details of the network sensory and control system according to the invention as shown in FIGS. **1–4**;

FIG. **6** is a schematic illustration of a touch memory port for use according to the present invention;

FIG. **7** is a diagram illustrating the internal components of a touch memory device to be used with the touch memory port of FIG. **6**;

FIG. **8** is a diagram further illustrating the use of touch memory with a touch memory port;

FIG. **9** is a schematic illustration showing circuitry that would be used with the touch collector, infrared collector, relay controller, or hybrid controller illustrated in FIG. **5**;

FIG. **10** is a schematic illustration showing circuitry used in conjunction with FIG. **9** to implement an infrared collector;

FIG. **11** is a schematic illustration showing circuitry used in conjunction with the circuitry of FIG. **9** to implement a relay controller;

FIG. **12** is a schematic illustration of a typical relay circuit that would be used in conjunction with the circuitry of FIG. **11**; and

FIGS. **13A** and **13B** are block diagrams showing typical network layers implemented according to the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The Hardware Environment

Turning now to the drawings, FIGS. **1–4** are block diagram illustrations of systems typically used to implement various aspects according to the invention. FIG. **1** shows a system implementing networked data collection with a single workstation. A logger and workstation PC **100** is connected to a hub **102** using standard networking hardware, preferably either Arcnet or Ethernet. The hub **102** is then connected to a concentrator **104**, and multiple concentrators can be present in the network. The concentrator **104** is connected to collectors **106** and **108** through a subnetwork,

preferably implemented using twisted pair wires. The collectors **106** and **108**, as can be seen, are daisy chained, and further collectors can also be used in the system. As will be discussed below in conjunction with FIG. **5**, the collectors **106** and **108** interface with various hardware sensing and control devices in the object tracking and location system implemented according to the invention.

FIG. **2** is a block diagram illustrating the single workstation embodiment of the invention shown in FIG. **1**, but with the hardware of the concentrator **104** placed within the logger and workstation PC **100** itself. In this system, the network has been eliminated, and the concentrator **104** would preferably directly communicate with any software desiring to communicate with the collectors **106** and **108**.

FIG. **3** illustrates yet another network embodiment according to the invention. In this embodiment, the logger PC **100** no longer acts as a workstation, but instead acts as a bridge between two networks. The first network is the equivalent to the network shown in FIG. **1**, including the hub **102** connecting to the concentrator **104**, which in turn connects to the collectors **106** and **108**. Again, the hub **102** is preferably for an Ethernet or Arcnet network.

The logger PC **100** then bridges to another network with a hub **200**. This can be any network, including a network other than an Arcnet or Ethernet. Workstations **202**, **204**, and **206** further connect to the hub **200** of this network. The workstations **202**, **204**, and **206** communicate with the logger PC **100**, which in turn communicates with the devices connected to the collectors **106** and **108**.

FIG. **4** illustrates yet another system according to the invention. In this system, the logger PC **100** does not bridge between hubs **102** and **200**, but instead simply connects to the hub **102** and communicates using standard networking protocols. In this configuration, the logger PC **100** communicates with the concentrator **104** using standard networking protocols, and gathers information from the concentrator **104** and controls various devices based on messages received from and sent to the concentrator **104**.

The workstations **202**, **204**, and **206** then communicate using standard networking protocols with the logger PC **100** to obtain information provided by the concentrator **104**. In this configuration, it is also possible for the workstations **202**, **204**, and **206** to communicate directly with the concentrator **104** or to "eavesdrop" on messages to the logger PC **100**. Generally, however, the workstations **202**, **204**, and **206** will receive information concerning the concentrator **104** only from the logger PC **100**.

FIG. **5** is a block diagram further illustrating various software control blocks and hardware in a system, such as the system illustrated in FIG. **4**, showing further details of the network object location and tracking system, along with the various devices that are part of that system. The logger PC **100** contains certain levels of software used to access the concentrator **104** on the network, the hub of which is the hub **102**. Typically, these software blocks include applications software running on a Windows operating system by Microsoft Corporation. This applications software communicates with the hub **102** through an event processor, which in turn includes an I/O message transport layer. The software is used to communicate through the local area network to the concentrator **104**, which has a unique identification. Of note, each concentrator **104** preferably has its unique identification embedded during the manufacturing process.

The concentrator **104** then communicates over a subnetwork to a touch collector **300**, an infrared collector **302**, a relay controller **304**, and a hybrid controller **306**. The touch collector **300**, infrared collector **302**, relay controller **304**, and hybrid controller **306**, are what are generically referred to as the collectors **106** and **108** in FIGS. **1–4**.

Each of these devices preferably includes an embedded microcontroller, an RS485 interface for communicating with the concentrator **104**, and firmware. Each of these devices preferably further includes a uniquely embedded identification code similar to that discussed in conjunction with the concentrator **104**.

The touch collector **300** includes interfaces for communicating with touch ports **308** and **310**, which in turn can receive a touch memory **312** with its own uniquely encoded identifications. Twenty-four such ports are shown, and they shall be referred to as "channels" of this "node," each collector or controller **300–306** being assigned a node number. The touch memory **312** is preferably manufactured by Dallas Semiconductor, Part No. DS 1990. Further details of these touch ports **308** and **310** and the touch memory **312** are further discussed below in conjunction with FIGS. **6–8**. It will be appreciated throughout this discussion that other registered serial number devices could be similarly used according to the invention, and touch memories are only a single application.

The touch collector **300** also includes an interface for an addressable transistor **314**, which in turn communicates with a passive infrared sensor (PIR) **316**. The addressable transistor **314** is a transistor which is activated by addressing it through a uniquely coded identification, such as that discussed in conjunction with the touch memory **312**, and is preferably implemented using Dallas Semiconductor Part No. DS 2405. These addressable transistors **314** and **316** each include a unique 48-bit identification code. By addressing that uniquely coded identification, communication can be established with the passive infrared sensor **316**. As with the touch memories, other devices than addressable transistors could similarly be used according to the invention. Thus, "addressable transistors" generically refers to devices that respond to a unique identification code to provide for electrical control.

Another addressable transistor **318** is connected to relay contacts **320** for controlling external devices, such as an electronic door lock.

The infrared collector **302** connects to infrared sensors **322**, **324**, and **326**. These infrared sensors receive transmissions from infrared TAGs **328** and **330**. These TAGs provide unique identification codes, similar to those discussed in conjunction with the concentrator **104**, and is also disclosed in U.S. Pat. No. 5,119,104, which is hereby incorporated by reference.

The TAG **330** receives its unique identification code from a touch memory **332**. The touch memory **332** provides a unique identification code for the TAG **330**, instead of the infrared TAG **330** including an embedded unique identification code such as the TAG **328**. This is further described in U.S. patent application Ser. No. 08/083,725, filed Jun. 25, 1993, entitled "A Method for Receiving and Transmitting Optical Data and Control Information to and from Remotely Located Recivers and Transmitters in an Optical Locator System," which is hereby incorporated by reference.

The relay controller **304** is used to control external devices.

The hybrid controller **306** combines the various aspects of the touch collector **300**, the infrared collector **302**, and the relay controller **304**, thus providing both sensors for touch memories, sensors for infrared TAGs, and control for external devices.

FIG. 6 is a schematic showing the details of the touch port 308. The touch port 308 is connected to the touch collector 300 via a jumper 400 with two signal lines SIG+ and SIG–. Between these two lines is a diode 402 preventing SIG+ from dropping below SIG–. The SIG+ line is also connected to the active portion of a touch memory receptor 404. The SIG– line is connected to the ground portion of the touch memory receptor 404. SIG+ is also provided through a diode 406 to light emitting diodes 408 and 410, which are in series, as well as to a piezoelectric sounder 412. The anode of the light emitting diode 410 is connected through a current limiting resistor 414 to the drain of an addressable transistor 416. The piezoelectric sounder 412 is similarly connected to the drain of an addressable transistor 418. The addressable transistors 416 and 418 are preferably part no. DS2405, manufactured by Dallas Semiconductor. The source of the addressable transistors 416 and 418 are connected to the SIG– line. The gates of the addressable transistors 416 and 418 are driven by the SIG+ line. These addressable transistors 416 and 418 include a unique identifying code that can be retrieved by signaling the addressable transistor to respond through their gates. This is documented in the Dallas Semiconductor product specification. The addressable transistors 416 and 418 are preferably selected such that the identification of the addressable transistor 416 ends in an odd digit, whereas identification of the addressable transistor 418 ends in an even digit.

The SIG+ line signal provided through the diode 406 is preferably additionally buffered by a capacitor 420, and its voltage is limited by a zener diode 422. SIG– is also limited below 40 V by a zener diode 424, which is connected to chassis ground.

In operation, when a touch memory device is placed into the touch memory receptor 404, it provides a signal via SIG+ and SIG– to the touch collector 300. The microprocessor in the touch collector 300 then queries the touch memory within the touch memory receptor 404 to provide its unique identification, which it does.

To control the light emitting diodes 408 and 410, as well as the piezoelectric sounder 412, the touch collector 300 provides a signal corresponding to the unique identifying code of either the addressable transistor 416 or 418. This causes that particular transistor 416 or 418 to turn on or off, appropriately enabling or disabling the visual or audio response.

In practice, when a touch memory device is placed in the touch memory receptor 404, its identification is passed up to the touch collector 300, which in turn passes both the port, or channel, number of the touch memory receptor, the unique identifying code of the touch memory device, and the unique identification code of the touch collector 300, on to the concentrator 104. The concentrator 104 in turn passes this information over the local area network to the logger PC 100. To acknowledge reception of this activation or deactivation, whichever may occur, the logger PC 100 then sends a message through the concentrator 104 to the touch collector 300, which enables the light emitting diodes 408 and 410, buzzes the piezoelectric sounder 412, or both, by supplying the unique identification codes to the addressable transistors 416 and 418. The logger PC 100 maintains a map of which addressable transistors 416 and 418 are associated with the particular touch memory receptor 404.

As an application, for example, suppose an employee keeps an identifying touch memory device on his keychain. To enter a facility, the employee touches the touch memory 312 into the touch memory receptor 404. The system recognizes that particular unique identifying code, and if that code representing that employee is authorized, activates the relay contacts 320 through the addressable transistor 318, disabling a magnetic door lock on a door corresponding to where the touch port 308 was located. The system further buzzes the piezoelectric sounder 412 and enables the light emitting diodes 408 and 410. The employee then enters. This is an application where a touch memory 312 would be preferable to a TAG, as the TAGs may be contained within the facilities themselves, whereas the touch memory 312 would be available at all times. The touch memory 312 could similarly be used within the facility at sensitive areas to prevent activation of doors by passing individuals and instead require the actual placement of the touch memory into the touch memory receptor 404. The touch memory 312 could similarly be used to identify part locations on an assembly line.

FIG. 7 illustrates the internal components of the Dallas Semiconductor touch memory itself. A touch memory chip 500 includes a multiplexer and a static RAM backed up by battery power. Further, the touch memory 500 contains a unique identification code not shown. The multiplexer, in response to an appropriate code, provides the data in the SRAM to the conductive portion of the touch memory 500. In this way, the touch memory can be polled and can return its unique identifying code.

FIG. 8 is a diagram further illustrating how the touch memory chip 500 is coupled to a host microcontroller 502. As can be seen, upon appropriate codes from the host microcontroller 502, the touch memory chip 500 memory array sequentially activates and deactivates an internal transistor 504, providing a signal to the host microcontroller 502. This is all further described in the Dallas Semiconductor materials regarding touch memories.

FIG. 9 is a schematic illustrating typical front-end circuitry used within the touch collector 300, the infrared collector 302, the relay controller 304, and the hybrid controller 306. These devices are typically daisy chained through RJ11 connectors 600 and 602, which form a link over the RS-485 twisted pair subnetwork. Power is provided through pins 1 and 2 of the connectors 600 and 602, filtered through an inductor 604, passed through a diode 606, and filtered by regulator circuitry 608, which provides filtered power VCC.

Ground is provided through pins 5 and 6 of the RJ11 connectors 600 and 602, through a zener diode 610, and further filtered by a filtering capacitor 612.

The signals on the RJ11 connectors are carried by pins 3 and 4, and are standard RS-485 signals. These signals are driven and received by a line driver 614, which is preferably an LTC 485 by Maxim Corp. The RO pin of the line driver 614 is connected to a receive input RXO of a microcontroller 616, preferably a DS2253 by Dallas Semiconductor, the RE line is connected to receive enable RE, the DE line is connected to transmit enable TXE, and the DI line is connected to a transmit output TXO. One general purpose port pin of the microcontroller 616 is pulled to VCC by a pullup resistor 626, but is also connected to an RSN (registered serial number) chip 628 that provides a unique serial number to the microcontroller 616. The RSN chip 628 is preferrably a DS 2200 by Dallas Semiconductor. The clock to the microcontroller 616 is provided by a crystal 620 across the crystal inputs to the microcontroller 616. These inputs are further filtered to ground through capacitors 622 and 624. The microcontroller 616 is further enabled by its enable input being pulled up to VCC through a resistor 626.

Local power is provided by rectifying V+ from the diode 606 through rectifier diodes 630, 632, 634, and 636. Voltage spikes on the local power are prevented using a transorb 630.

The microcontroller 616 has general purpose input/output channels illustrated as A0–A7, B0–B7, and C0–C7. Lines C0–7 are shown to be pulled up to VCC through a resistor pack 640, and can in turn be pulled down by the microcontroller 616 through its PSEN output. Lines A0–A7 and B0–B7 are similarly pulled up and down by circuitry not shown.

When the circuitry of FIG. 9 is implemented in the infrared collector 302, additional circuitry, shown in the schematic of FIG. 10, provides signals from the sensors 332–326 to the channels of the microcontroller 616. A comparator 714 is coupled to one of the sensors 332–336, and provides a high voltage output in response to a signal being received by that sensor. Similar sensing is provided by comparators 716 through 728. These comparators are preferably LN339 devices, single supply, low powered, low offset voltage quad comparators. The outputs of the comparators 714 through 728 are provided to the channel inputs of the microcontroller 616 in FIG. 9. The microcontroller 616 thus receives signals passed from TAGs through the infrared sensitive diode 700, and forms appropriate messages for transmission on the subnetwork.

In the relay controller 304, circuitry illustrated by the schematic of FIG. 11 is used. In this configuration, the ports of the microcontroller 616 are implemented as outputs, and are connected to five chip enable lines CE0*–CE04*, to a clear line CLR*, to a data line DATA, and to three device select lines A0–A2. In this disclosure, an "*" indicates logical active low signal. CE0*–CE04* are provided to latching decoders 800 to 808, with one chip enable line being provided to each. CLR* is provided to the clear inputs of each of the latching decoders, DATA is provided to the data input of each latching decoder, and A1–A3 are provided to the address lines of the latching decoders. Using this circuitry, the 40 outputs of the latching decoders 800–808 can each separately drive a relay driven device. A write command with a particular chip enable selected, say CE0*, and with the address lines appropriately set, such as to 000, will thus latch the data to the data input of latching decoder 802 to its Q0 output. In this way, the states of each of the 40 outputs can be set.

FIG. 12 illustrates how the outputs of these latching decoders would be implemented. A Q output of one of the latching decoders 800–808 is provided as the return line RET to a relay 900, the other side of which is connected to V+. When the Q output connected to the relay 900 goes low, this energizes the relay, causing the outputs to go to an activated state. When the Q output goes high, the relay 900 is deactivated. Using these relays, a variety of external devices can be controlled, such as magnetic door locks and the like.

The touch collector 300 is implemented with circuitry similar to that used to implement the infrared collector 302 as illustrated in FIG. 9. The various channels of the microcontroller 616 are directly connected to the signals provided on the jumper 400 of FIG. 6 for each of the various touch ports. Similarly, the gate of the addressable transistors 314 and 318 are similarly connected to channels of the microcontroller 616. Because the channels of the microcontroller 616 are programmable as inputs or outputs, the touch port 308 can be accessed either by writing to the addressable transistors 416 and 418, or by reading from the touch memory receptor 404.

Passive infrared sensor 316 and relay contacts 320 are then accessed through the addressable transistors 314 and 318 by standard circuitry. The relay contacts 320 are opened and closed using the addressable transistor 318 with circuitry similar to that illustrated in FIG. 6, whereas the passive infrared sensor 316 would have a channel enable to the microcontroller 616 by turning that channel on using the addressable transistor 314, which is connected to the same channel.

It is to be noted that the relay controller 304 does not include addressable transistors, whereas the touch collector 300 does include addressable transistors 416, 418, 314, and 318 to access the passive infrared sensor 316, the relay contacts 320, and the light emitting diodes 408 and 410, as well as the piezoelectric sounder 412 and the touch port 308.

In conjunction with the touch port 308, the SIG-line would be connected to ground within the touch collector circuitry of FIG. 9, whereas the SIG+ line would be connected to the appropriate port of the microcontroller 616. The ports of the microcontroller 616 would appropriately be configured as inputs or outputs depending on whether data was being received from the touch memory receptor 404 or the adjustable transistors 416 or 418, or was being sent to those devices. Thus, 24 touch ports 308 could be connected to a single touch collector.

The concentrator 104 is effectively implemented as an intelligent interface between the Arcnet or Ethernet network and the twisted pairs RS-485 subnetwork. Similar to the controller circuitry illustrated in FIG. 9, and it preferably includes a microcontroller, as well as interface circuitry for both of the networks. Further, preferably includes an RSN chip, such as the RSN chip 628 in FIG. 9.

The Network Layer

FIG. 13A and 13B illustrate the typical network layers involved in the disclosed embodiment. These are particularly described for a touch collector 300 used in the system illustrated in FIG. 3. The microcontroller 616 within the touch collector 300 preferably implements software containing the following layers. The touch physical interface is accessed by the microcontroller 616 through a bit level touch protocol, a byte level touch protocol, and a page read/write protocol. These protocols are in turn provided to the subnetwork through a subnetwork interface, a subnetwork I/O kernel, and a RS 485 physical interface.

The subnetwork is accessed by the concentrator 104 again through an RS 485 interface, which is accessed via a subnetwork I/O kernel in a microcontroller within the concentrator 104. The microcontroller within the concentrator 104 then provides a network interface, in this case ARCNET, through an ARCNET interface driver and an ARCNET physical interface. The ARCNET network provides messages to or from the concentrator 104 to the logger PC 100. The logger PC 100 again includes an ARCNET physical interface, and its software includes an ARCNET interface driver. A bridge/buffer application is run within the logger PC 100, which then provides Windows based messages through a usernet netbios to the principal network. The workstation 202 can then receive these Windows based messages through its own usernet netbios, via a page read/write protocol, an operating system, and a file-oriented touch application.

SNMP, or simple network management protocol, is a well known network communication protocol based on a variable paradigm. An SNMP server responds to Get, GetNext, and

Set messages from a client. In the disclosed embodiment, the concentrator **104** acts as the SNMP server, while the logger PC **100** acts as the client.

The server maintains a management information base (MIB) that defines a set of conceptual variables that the SNMP server must maintain. Sometimes these are actual variables, other times these are parameters generated by performing various functions or, in the disclosed embodiment, received from a controller or collector **300–306**.

MIB variables have names, and according to the ISO standard, the standard prefix is "1.3.6.1.2.1". These variable names are transmitted in a numeric form of the ASN.1 format, an ASCII format in which each sublevel of the variable is separated by periods. Because this listed header is always used, it is generally omitted internally by the SNMP server.

In the disclose embodiment, a standard additional prefixes is added, . . . 99, . . . which indicates that the SNP in object identifier variables being accessed are the SNOIDs or subnetwork variables.

Further discussion of SNMP can be found in DOUGLAS E. COMER AND DAVID L. STEVENS, INTERNETWORKING WITH TCP/IP VOL. 2-DESIGN, IMPLEMENTATION, AND ETERNALS (2D ED. 1994) Chapter 20. SNMP is well known to the data communications art.

In the disclosed embodiment, the subnetwork, through the concentrator **104**, appears to the logger PC **100** as the SNMP server. As noted above, SNMP uses a variable paradigm, and its messages provide for getting and setting variables of the system using object identifiers (OIDs). To provide for a uniform interface to the network, the objects on the subnetwork in the disclosed embodiment are identified through subnetwork object identifiers (SNOIDs). These SNOIDs are accessed using standard SNMP protocol.

Software applications on the logger PC **100** use the SNOIDs interface to receive stimuli from the subnetwork based on those stimului. The logger PC **100** then logs, controls, or causes certain actions to take place. The stimuli typically are received messages from the infrared tags **328** and **330** (such as the identification), from the touch memory **312**, or from the PIR sensor **316**. Using SNOIDs, the logger PC **100** in turn controls such physical devices as the relay contacts **320** and the piezoelectric sounder **412** and the leds **408** and **410**.

To the external world, SNOIDS and the subnetwork constitute an SNMP server. The concentrator **104** is accessed directly over a LAN or Wide Area Network (WAN) as an SNMP server. These networks are preferably Ethernet or ARCNET. Client applications communicate with these servers using UDP (a protocol that is part of the TCP/IP suite). An SNMP server manages a block of variables (MIB) whose values clients can access using Get and Set. Variables within the server are addressed via Object IDentifiers (OIDs). An OID is represented as a sequence of decimal numbers seperated by decimal points. The variable-length data that is Get and Set is encoded using ASN.1, a standard encoding format, and can be of several different types. Should the SNMP server encounter an error condition of a general nature or need to report a change of state, a Trap Protocol Data Unit (PDU) is broadcast to the attached network.

SNOIDs are preferrably accessed by applications on the workstations **202–206** and the logger PC **100** through the network and subnetwork using Dynamic Link Library protocol using the Microsoft Window's DLL mechanism. DLL provides not only the ability to receive real-time stimulus events from the subnetwork, but also to access and set the

SNOIDs variables contained within the subnetwork itself. The SNOIDS Applications Program Interface (API) provides for transparent access to the subnetwork regardless of the topology of the network between the application and the server.

The DLL handles all of the SNMP protocol specific requirements for communicating with the subnetwork server, including the ASN.1 encoding of any data as well as properly encoding OIDs. The DLL submits the SNMP Set, Get, and GetNext PDUs on behalf of the clients using it. In addition, the DLL provides storage for all incoming PDUs for its subnetwork clients and provides for the translation of this data into Stimuli Reports as well as Tag Reports. Finally SNOIDs handles the posting of appropriate Responses and Traps to the Window's message queues of the tasks using it functions.

Subnetwork OIDs (SNOIDs)

SNOIDs are used to communicate with the subnetwork, making SNOIDs the subnetwork's "language." All system variables of the subnetwork have been given unique OIDs. This is a very rich set of variables that includes such items as ASCII names for every component within the subnetwork as well as firmware revision levels. Even the actual memory of the embedded micro-processors within the concentrators **104** and collectors and controllers **300–306** can be accessed and set; in fact, OIDs are used to download new code to the concentrators **104** and collectors and controllers **300–306**.

OIDs and Registered Serial Numbers

All of the components of the subnetwork have within them a Registered Serial Number (RSN) which is guaranteed to be unique. This number is derived primarily from an identification part manufactured by Dallas Semiconductor, but can be derived from any unique source of identifications. The concentrators **104** and collectors and controllers **300–396** can be accessed directly by appending their RSN to an OID. Furthermore, any device in contact with the touch ports **308** and **310** can be accessed and, if appropriate, set via a unique OID. Similarly, the various addressable transistors **314**, **318**, **416**, and **418** are accessed using SNOIDs.

Subnetwork Stimuli Report OIDs

Subnetwork stimuli are stored in a series of eight consecutive OIDs. The set of these OIDs provides a "sliding window" that clients can access by issuing Get requests. If no stimuli data is currently stored in the accessed variable, then the Get's response is delayed until a stimulus arrives from the subnetwork. In addition, an OID is available that has as its value the current OID that is receiving stimuli reports from the subnetwork.

For example, a typical client application desiring all of the stimuli reports from the subnetwork first performs a "logon" to the the server by sending the SNMP Get request (OID 96.0.0.0) to obtain the current stimuli event OID. If the current OID that has the latest stimuli data is 96.0.0.0.3, then this is returned. The client application then issues a request to Get this OID. The SNMP subnetwork server saves the client's request and, when data is available for this OID, passes it back to the client. The client then increments the last number of the OID (the "sliding-window's" sequence number) modulo eight and issues a Get for the next stimuli report (in this example, OID 96.0.0.0.4). Using a timer, the client then periodically checks to make sure that its current stimuli OID value is "in-sync" with the server (by checking

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the value of OID 96.0.0.0), and if there is a discrepancy, reissuing Gets for any missed sequenced OIDs.

The preceding algorithm is actually implemented within the SNOID's DLL whenever a Get OID of 96.0.0.0 is issued with the GetModifiers set to Continuous and Sequential. After this call is made to the SNOID's API, the task will have posted to its message queue all stimuli events from the subnetwork. Stimuli reports made in this manner are also referred to as "Unsolicited Get Requests."

Whenever multiple responses to a Get request can occur, it is necessary to use the Continuous modifier. Without the use of this modifier, the first response to the request will cause the deletion of the original request from an internal table and any potential subsequent responses from the subnetwork will be discarded. Note that if the subnetwork includes multiple concentrators **104** then it is necessary to send the request as a broadcast by either specifying an IP Address of FF.FF.FF.FF or leaving the IP Address empty (NULL). Using this technique is convenient for finding all of the concentrators **104** that are on a network.

Subnetwork OIDs that Trigger External Events

It is possible to Set specific OIDs within the touch collector **300** that will effect a contact closure. In this way, it is possible to extend the subnetwork to trigger external events, such as the unlocking of a door via the relay **320**.

SNOIDs used in the Preferred Embodiement

This section defines Objects in the Management Information Block of the SNMP subnetwork implementation.

A subnetwork Object Identifier is specified in the following manner:

<resource class>.<variable number> [.<index>[.<sequence number>[.<RSN>]]]

Note that the ".96" prefix is added to indicate the SNOIDs MIB is being acessed.

Resource Class

Each resource (collector, etc.) may be assigned a Resource Class that can be used to separate or group resources in the network. A Resource Class value of zero is the general case and is accepted by all resources. Resource class assignments are arbitrary.

Variable Number (value class)

Each subnetwork resource supports variables in three groups. Variables 0,1,2 and 3 are fundamental to all devices and are supported even when the loadable firmware is not functional. Variables 5 through 13 are largely universal among resources. Variables above 13 are resource-specific.

Each subnetwork resource contains a variable which is an array of variable names supported by the device. The symbolic variable names used in this table are shown below under the "symbol" heading.

Array type variables use the value subclass in the OID as an element specifier (array index).

Get operations are issued without values. Set operations require that values be provided. If the values provided do not match the type and length of the destination variable, an error is returned and the Set does not occur (an indirect Set is the sole exception).

Fixed (universal) variables 0,1,2, and 3

The fixed variables are common to all resources and are the only variables that remain valid during firmware downloading. The indirect access variable performs a variable length octet string Set or Get starting at the physical memory address provided in the indirect access pointer variable. Accesses below 0800H will yield invalid results. A Get performed using the indirect variable will return the number of bytes specified by the value subclass. A Set performed in this manner sets the number of bytes provided in the octet string value provided, and the value subclass in the SNOID must match this number or an error will occur.

The following is a description of the different variables and their functions:

StimRep { 0 }
Syntax: Sequence of Stimulus
Definition: A set of stimulus reports. Variable type 0 will not be issued to a subnetwork resource. This variable is reserved for the upchannel return of unsolicited stimulus reports.
Access: read.
Stimulus { StimRep }
Syntax: Sequence
Definition: Location OID
StimulusId Octet String
Qualifiers Octet String
Access: Read.
Indirect { 1 }
Syntax: Octet String (length variable)
Definition: Indirect Memory Access in Collectors and Concentrators
Access: read-write.
MemAddRec { 2 }
Syntax: Integer (length 2)
Definition: Indirect Memory Access Pointer.
/Access: read-write
LoadStatus { 3 }
Syntax: Integer (length 1)
Definition:Download Status.
Access: read-write

General Variables 4 through 13

DeviceType { 4 }
Syntax: Printable String (length 25)
Definition: Device type string.
Access: read.
LoadRev { 5 }
Syntax: Printable String (length 15)
Definition: Loader revision/date
Access: read.
DeviceName { 6 }
Syntax: Printable String (length 25)
Definition: Device name string.
Access: read-write.
SystemName { 7 }
Syntax: Printable String (length 25)
Definition: System name string.
Access: read-write.
FirmRev{ 8 }
Syntax: Printable String (length 15)
Definition: Firmware revision/date.
Access: read-write.
RSN { 9 }
Syntax: Octet String (length 8)
Definition: Resource serial number.
Access: read.
NodeID { 10 }
Syntax: Integer (length 1)
Definition: Subnetnode id.
Access: read.
UserNumber { 11 }
Syntax: Printable String (length 25)
Definition: User assigned information.
Access: read-write.
VarTable { 12 }

-continued

Syntax: Sequence VarName
Definition: Variable name table.
Access: read.
VarName { VarTable, 0 }
Syntax: Printable String (length 15)
Definition: Variable name.
Access: read.

Subnetwork Specific Variables

MaxNodeID { 16 }
Syntax: Integer (length 1)
Definition: Maximum resource node ID.
Access: read.
RSNTable { 17 }
Syntax: Sequence of RSNEntry
Definition: Resource serial number table.
Access: read.
RSNEntry { 0 }
Syntax: Octet String (length 8)
Definition: Resource serial number.
Access: read.
MsgNoNode { 18 }
Syntax: Printable String (length 25)
Definition: Message for "No Collectors Found"
Access: read.
MsgNodLost { 19 }
Syntax: Printable String (length 25)
Definition: Message for "Node Lost"
Access: read.
ArcnetNode { 20 }
Syntax: Integer (length 1)
Definition: Subserver node number.
Access: read-write.

Collector Specific Variables

MaxNodeID { 16 }
Syntax: Integer (length 1)
Definition: Maximum resource node ID.
Access: read.
RSNTable { 17 }
Syntax: Sequence RSNEntry
Definition: Resource serial number table.
Access: read.
RSNEntry { 0 }
Syntax: Octet String (length 8)
Definition: Resource serial number.
Access: read.
MsgNoNode { 18 }
Syntax: Printable String (length 25)
Definition: Message for "No Collectors Found"
Access: read.
MsgNodLost { 19 }
Syntax: Printable String (length 25)
Definition: Message for "Node Lost"
Access: read.

Infrared Collector Specific Variables

SensNameTable { 14 }
Syntax: Sequence (elements 128)
Definition: Table for Sensor names.
Access: read-write.
SensName { SensNameTable n }
Syntax: Printable String (length 25)
Definition: sensor name.
Access: read-write.
SensClassTable { 15 }
Syntax: Sequence (elements 128)
Definition: Sensor class table
Access: read-write.
SensClass { SensClassTable n }
Syntax: Integer (length 1)
Definition: Sensor Class
Access: read-write.
DemodOR { 16 }
Syntax: Integer (length 2)
Definition: Demod overrun count.
Access: read-write.
ShortCnt { 17 }
Syntax: Integer (length 2)
Definition: Short bit error count.

-continued

Access: read-write.
LongCnt { 18 }
Syntax: Integer (length 2)
Definition: Long bit error count.
Access: read-write.
StartCnt { 19 }
Syntax: Integer (length 2)
Definition: Long bit error count.
Access: read-write.
ParErrCnt { 20 }
Syntax: Integer (length 2)
Definition: Parity bit error count.
Access: read-write.
AuxErrCnt { 21 }
Syntax: Integer (length 2)
Definition: Auxilliary bits error count.
Access: read-write.
CRCErrCnt { 22 }
Syntax: Integer (length 2)
Definition: CRC error count.
Access: read-write.
NibErrCnt { 23 }
Syntax: Integer (length 2)
Definition: Check nibble error count.
Access: read-write.
LenErrCnt { 24 }
Syntax: Integer (length 2)
Definition: Bad message length count.
Access: read-write.
OvrErrCnt { 25 }
Syntax: Integer (length 2)
Definition: Buffer overflow count.
Access: read-write.
TMAErrcnt { 26 }
Syntax: Integer (length 2)
Definition: TMA (Ack) failure count.
Access: read-write.

Touch Collector and Relay Controller Specific Variables

BeepPort { 16 }
Syntax: Integer (length 1)
Definition: Port number to Beep. The port BLINK and BEEP variables are normally set to OFF (hex) by the collector. When one of these variables is set to a port number (1–24), the BEEP or BLINK devices associated with that port are activated momentarily, after which the variable value is returned to OFF (hex).
Access: read-write.
BlinkPort { 17 }
Syntax: Integer (length 1)
Definition: Port number to Blink. See description of BeepPort for more information.
Access: read-write.
TAWOTMA { 18 }
Syntax: Integer (length 2)
Definition: Ack failure count.
Access: read-write.
OpenDoor { 19 }
Syntax: Integer (length 2)
Definition: Port number to pulse. This variable is used in access control developement.
Access: read-write.
TimEvTable { 20 }
Syntax: Octet String (length 11)
Definition: Timed event table. This variable is used in access control developement.
Access: read-write.
LastRSN { 21 }
Syntax: Octet String (length 8)
Definition: Last arrived RSN. This variable is used in access control developement.
Access: read.

Error Codes

Value:	Symbol:	Meaning:
01	Err_TooLong	OID length excessive
02	Err_NoOid	OID not valid for this device
03	Err_BadVal	Value bad or missing value

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-continued

04	Err_BadOid	Malformed OID header or NetClass<>Servant Net
05	Err_UnLoad	No valid program loaded
06	Err_NotForMe	Message to my Node ID not for me
07	Err_MultiZer	Multi element array index invalid (zero, too large)
08	Err_PDUType	PDU type is not SET or GET
09	Err_VType	Bad variable type in SET
0A	Err_VLen	Bad variable length in SET
0B	Err_IndLen	Indirect variable length = 0 in SET
0C	Err_ReadOnly	Attempt to SET a read-only variable

Programming at the Network Layer

Programming Environments for SNOIDs

If the application is run under the Microsoft Windows 3.1 operating system then there is a rich set of development tools available to both Visual Basic programmers and C/C++ programmers through the use of the SNOIDs DLL and VB custom controls.

If the software platform of the client is not Microsoft Windows or an interface that allows Remote Program Calling, then a programming aid for obtaining subnetwork information over a TCP/IP network are the list of OIDs supported by the subnetwork. By sending correctly formatted SNMP requests to the subnetwork server using UDP ports, however, full access to its data can be achieved.

In addition a suite of files are preferably maintained by the subnetwork information processing system in the logger PC **100**. A typical application is found in U.S. patent application Ser. No. 08/118,566, filed Sep. 9, 1993, entitled "Method and Apparatus for Locating Personnel and Objects in Response to Telephone Inquiries," which is hereby incorporated by reference.

Programming SNOIDs in a Window's Visual Basic Environment

In order to make stimuli easily available for Visual Basic (VB) programmers, custom controls can be developed. These controls invoke the SNOIDS DLL, so that the VB programmer has a protocol that correctly parameterizes calls to the SNOIDS API and posts messages from the subnetwork onto the appropriate VB message queue. These messages in turn trigger Visual Basic events. By adding these controls to a VB application and including it in a "form," the application will have access to the capabilities of the SNOID's DLL.

The STI custom control would give the user full access to all stimuli events of the subnetwork. Upon activation of any form that contains a STI control, communications are set up through the SNOIDS DLL for posting all stimuli received from the subnetwork to the VB program. For example, stimuli could be received via a form's event titled StimulusReport for the STI control.

StimulusReport Event

The reception of a stimulus event could parameterized as follows:

```
Sub Stimulus1_StimulusReport (Channel As
String, CollectorID As String, IpAddr As
String, StimulusId As String, ReceptorClass As
String, Qualifiers As String) EndSub
```

Channel and CollectorId parameters are the unique collector or controller **300–306** and channel that define the receptor reporting the event.

IPAddress is the IP address of the concentrator **104** connected to the subnetwork that has reported the event.

StimulusId is the unique id of the stimulus.

ReceptorClass is the class of the receptor that has detected this event.

Qualifiers are stimulus dependent additional information that is associated with the event. In the case of infrared tag reports, this information includes the state of the tag's battery, its motion switch and its current "TCOUNT."

Visual Basic Custom Control for SNOIDs.

The SNOID custom control would provide the application with the ability to generate an SNMP request to the subnetwork server and receive its response. Once the control is "dropped-onto" a VB form, an SNMP request would be sent out anytime the PDUType property is modified. This action will take place during either design- or run-time. In addition, during run-time, a SNOID response event would be triggered when the response is returned from the SNMP server for the request. During design time, the VB programmer would be notified that the request has been successfully completed by the fact that the PDUType property will change to Response.

SNOID Properties

The following are the special properties that would be asscociated with SNOID control.

Error Types

Returned from DLL

This is an enumerated property that reflects the Error Type returned for a SNMP request. Normally this value will be either OK or User-Defined. If User-Defined is returned then the Error Value property contains the specific error.

Error Values

Returned from DLL

This property reflects the specific error for a SNMP request. It is only valid if the Error Type is not OK. It is enumerated.

Get Modifiers

Set by programmer

This enumerated field consists of a combination of four possible modifiers for any SNMP Get request. These modifiers qualify how the SNOID's DLL interprets the SNMP Get request in the following manners:

Continuous—issues the Get request and initiates another Get request upon reception of the first request's response. This process will continue until the DLL or the task that commences the original Get terminates.

Sequential—used in conjunction with the "96.0.0.0.x" Stimuli Report OID. This modifier will increment the value of "x" modulo the size of the stimuli report "sliding-window" (8) each time it receives a response.

Polled—broadcast the Get every five seconds and continues this until the DLL or the task that commences this Get terminates.

Note that the use of Sequential and Polled modifiers are only supported for the particular OID 96.0.0.0; use of these modifiers in other OID Get requests is not defined. The Continuous modifier is useful in "Broadcast" requests and is supported for all OID values.

IPAddress

Set by programmer/Returned from DLL

Twelve hexi-decimal digit string representing the IPAddress of the SNMP server. Setting a null value is interpreted to be a broadcast ("ff ff ff ff"). Notice that all hex strings are represented by groups of two hex digits followed by a space, for example SNOID.IPAddress="01 0a 03 0c". Hex digits are comprised from 0–9 and A–F (or a–f).

OID

Set by programmer/Returned from VBX when OID Hex changes (below)

This property is a string composed of dot seperated decimal digit sequences that composes the OID for the SNMP Get request. Note that the standard SNMP preamble of "1.3.6.1.2.1" is automatically prefixed to any string entered here, so it must not be included. Also, all subnetwork specific SNOIDs start with 96. For example, to query a Concentrator as to its DeviceName, the OID would be "96.0.6.0.0".

OIDHex

Set by programmer

Whenever the programmer enters a hexi-decimal digit string into this property, the OID property is changed to reflect the ASN.1 decimal equivalent. Using this property allows translation of an RSN into ASN.1 decimal equivalent form. Note that this action occurs only if the OID property is cleared prior to the setting of the OIDHex property.

PDUType: Set by programmer/Returned by DLL

The setting of this enumerated property to Get, GetNext, or Set triggers the sending of the SNMP request. The return of the response will be reflected by the PDUType being changed to Response.

Value

Set by programmer for Set/Returned by DLL for Get and GetNext

This property is a string that reflects the value for an OID. For Get requests, the property is valid when the response returns. For Set requests, the value of the OID within the SNMP will be changed to the value entered here. Note that the form of this value is dependent on the ValueType for the OID. Also, the DLL will provide the ASN.1 encoding/decoding of this value within the SNMP request/response.

ValueHex

Set by programmer for Set/Returned by DLL for Get and GetNext

If the Value property is empty, then the hexi-decimal digit string entered here will be used for the value of a Set request. Upon reception of a response, this property is set to the hex string equivalent of the Value property.

ValueType

Set by programmer for Set/Returned by DLL for Get and GetNext

This enumerated property is the ASN.1 value type for the value property.

SNOIDResponse Event

During runtime, a SNOIDResponse event is invoked whenever a response for-a Set, Get, or GetNext OID that had been issued previously by the VB application is received by the SNOID's DLL. All properties that are set by the control are valid and can be interrogated and acted upon at this time.

SnPollOid External Procedure

When the SNOIDs DLL is used with an ARCNET card or IOCard, the hardware must be polled to receive incoming messages. Normally this is done via a timer from within SNOIDs automatically. If the user wishes to control the polling of the hardware, then insertion of this call will provide this functionality.

The SNOID's DLL can be accessed via call to the API as outlined in SNOIDAPI.H, attached as Appendix 1. The functions provided allow clients to send and receive SNMP messages in the PDU store. One of ordinary skill in programming for Microsoft Windows' message queues will understand how to program this API.

SNMP Set, Get, and GetNext can be sent through the SNOID's DLL using the snSetOid, snGetOid and snNextOid functions, respectively. SNOIDAPI.H shows the actual parameters for the IPAddress, OID and Values. The Responses for these calls will be returned on the Window's message queue.

Reception of an SNMP Response or Trap is detected through a message in the Window's message queue as events WM_SNOIDRESP and WM_SNOIDTRAP, respectively. The LPARAM is a handle into the PDU store of the object received. The SPARAM is a sequence number so that any "wrap" of the PDU store can be detected Should the processing of the message not occur before the data is invalidated by subsequent incoming messages. Both LPARAM and SPARAM are returned by any call accessing the data within the PDU store.

Properties of the PDU Objects

The values for these properties can be obtained by calling the appropriate routine of the API with the objects handle and sequence number. Any of these functions will return FALSE if an invalid handle or sequence number are detected. The following is a list of the properties.

PDUType: Accessed by snWotPduType

IPAddress: Accessed by snWotIPAddr

OID: Accessed by snWotOid and snWotRawOid

ValueType: Accessed by snWotValType

Value: Accessed by snWotVal

ErrorType: Accessed by snWotErr

ErrorValue: Accessed by snWotErrX Processing Functions SnPduAck

SnPduAck is provided to let the PDU store know that the application has processed this message. Note that objects within the PDU will be invalidated even though they have not been fully acknowledged.

SnTagRep and SnStimulusReport

These functions provide an ability to extract the data from the value of a Stimuli Report OID (96.0.0.0.x). These functions should be called repeatedly initially with the which parameter set to zero as multiple Stimulus Reports could be contained within a PDU. When the which parameter is greater than or equal to the number of Stimuli Reports within a PDU, the function will return FALSE.

SnPollOid

When hardware that connects the SNOID's computer with the subnetwork needs to be polled to function correctly, then the snPollOid routine should be called within the Window's main loop. Please see the section in the Visual Basic section on this topic for more information.

The Subnetwork

Physical layer

The physical layer of the subnetwork is preferably twisted pair to RS-485 drivers that are tri-stated for multi-drop configurations.

Data Link Layer

A single binary data element (bit) is defined as a period of four microseconds during which the state of the data pair remains constant at either a logical zero or logical one potential difference. The differential voltage of the data pair reflects the value of the binary data element in that the pair idles in a marking (one) state and is driven to the spacing (zero) state.

A single symbol consists of eleven bits in sequence, the first always being a logical zero state (start bit). The second through ninth bit periods are eight binary bits in order, least significant first, of the symbol value. The tenth bit period is a control state used to cause selected symbols to invoke receiver interrupts, called an Alert Flag bit. The eleventh (final) bit period is a logical one state (stop bit). A single symbol has a time period of 44 microseconds (11*4 usec).

System messages consist of symbols or groups of symbols which have meanings in the system control protocol. Multi-symbol messages are made up of symbols with less than **100** micro-seconds between the first symbol stop bit and subsequent symbol start bit.

The alert flag bit may be set to the true state in the leading symbol of selected messages, but not in any other symbols of the message.

A data packet may consist of between 11 and 259 symbols which have no more than 100 microseconds between any symbol stop bit and the subsequent symbol start bit. The alert flag bit is set to the true state in the leading symbol of every data packet, but not in any other symbols of the packet.

Subnetwork Layer

The concentrator **104** controls the exchange of information on the subnetwork through the use of special messages which direct the subservient nodes in their use of the media. To move data between applications, which are serial number oriented, and the subnetwork nodes, which are node number oriented, the concentrator **104** maintains a list of serial numbers present on the subnetwork and the nodes that those serial numbers each occupy.

Although the disclosed subnetwork operates using polling, one could easily implement another non-polled technique, such as CSMA (collision sense multiple access). The same holds true for the network layer.

Subnetwork Packet Types and Functions
Invitation To Transmit (ITT)

Offset:	Len:	Name:	Function:
0	1	DID*	Destination ID (1 < DID < 255)
1	1	SID	Source ID = 0

Note:
*indicates that interrupt flag is set on this symbol.

The Invitation To Transmit message can only be issued by the concentrator **104** device. It is comprised of a symbol, which is the number of the node being invited to transmit, followed by a symbol which is always zero.

When a subnetwork node receives an Invitation To Transmit in which the leading symbol equals its node number, that node is enabled. An enabled node will remain so until it issues a Pass message (see below), or until 800 microseconds pass during which there is no transmission or reception of symbols by the node.

When a node has been enabled, it may transmit a data packet to any other node. An enabled node which has transmitted a data packet must now wait up to 800 microseconds for an acknowledgment response from the destination node. If no response is observed, the node will issue the Pass message and leave the enabled mode, assuming an unsuccessful data transmission has occurred.

If an enabled node observes any other data transaction on the network other than an appropriate acknowledgment message after sending a data packet, it will leave the enabled mode immediately and issue no further transmissions.

Pass

Offset:	Len:	Name:	Function:
0	1	DID	Destination ID = 0

The Pass message may only be issued by a node which has been enabled by receiving an Invitation To Transmit, and which remains enabled. This message is used by an enabled node to signal to the concentrator **104** that it has completed network data transactions and is no longer enabled. This message consists of a leading symbol which has a value of zero.

An enabled node with data to transmit will perform the data transmission and then issue a Pass message. An enabled node with nothing to transmit will issue a Pass message immediately. In either case, the Pass message must be issued within 800 microseconds of the node being enabled or the end of the last data transmission generated or observed by the node.

Invitation To Join (ITJ)			
Offset:	Len:	Name:	Function:
0	1	DID*	Destination ID = 255
1	1	SID	Source ID = 0

Note:
*indicates that interrupt flag is set on this symbol.

The Invitation To Join message may only be issued by the concentrator **104**. It is comprised of a symbol with the value of 255 (decimal) followed by a symbol with the value zero. The alert flag is set to true in this message. This message is used to invite any nodes that have been omitted from the polling sequence to signal the concentrator **104** if they wish to join the polling sequence.

Any node which receives two ITJ messages without being enabled one or more times between them must assume that it has been omitted from the polling.

Acknowledgement (ACK)			
Offset:	Len:	Name:	Function:
0	1	ACK	Issuer node number (1 < ACK < 255)

The Acknowledgment message (ACK) is issued by a node which has received a data packet to signal that the packet has been received without error. This message is comprised of a leading symbol which has a value of the node number of the recipient resource.

Data Packets

Data is transferred between nodes using a data packet structure as follows:

Offset:	Len:	Name:	Function:
0	1	DID*	Destination ID (0 < DID)
1	1	SID	Source ID (0 < SID < 255)
2	1	COUNT	Count (0–255, 0 = 256 data bytes)
3	1	PSN	Packet Sequence Number
4	1–256	DATA	Application data area
5–260	1	CRC	Error control

Note:
*indicates that interrupt flag is set on this symbol.

The CRC value is generated by performing an XOR against each data byte of the message and then a single left shift of the result. The initialization value is zero.

Node Search Mode Command

The Node Search mode is invoked in the subnetwork using the Search Mode Command message. Any node receiving this command will enter the Node Search mode.

Offset:	Len:	Name:	Function:
0	1	DID*	Destination ID = 255 (Broadcast)
1	1	SID	Source ID = 255 (Special Code)

This command message may be issued more than once to insure that all nodes enter the Node Search mode.

Node Search Message

The Node Search Message is an exception to normal network formats and is used during the special node search mode, in which nodes are identified and provided node numbers. The search mode message is a single symbol formatted as follows:

Offset:	Len:	Name:	Function:
0	1	SRCH	Search Message Code
		0–47 =	Test Bit 0 thru 47
		65 =	Select All (Reset)
		66 =	Select Ones
		68 =	Load Node ID (followed by node ID, then complement of node ID)
		72 =	Test All
		80 =	Match Report

The interrupt flag bit is not set in these messages. If a node receives a character in which the interrupt flag is Set, the node will abort the Node Search mode.

Polling of Nodes The concentrator **104** polls the subnetwork. It maintains a count of the number of assigned node numbers in a subnetwork and polls those nodes in sequence.

Subnetwork Changes and New Nodes

About once per second, an Invitation To Join message is issued by the concentrator **104** allowing any network node to signal that node numbers must be reassigned. If any node causes sufficient network activity during this interval, the concentrator **104** will perform a Node Search operation and re-establish (and possibly reassign) the network node numbers.

Addition of Nodes

If a new node is added to the subnetwork, it will not have a valid node number and will not be polled. To correct this, a new node may signal the need for a subnetwork Node Search action. The concentrator **104** issues a periodic Invitation To Join signal. Any node wishing to enter the polling will transmit data in response to this message. If this message gets a response on a number of consecutive ITJ's, the concentrator **104** will perform a Node Search.

Node devices find themselves conflicting with other nodes.

Data Exchange

A data packet includes between 6 and 261 symbols. The first symbol is the destination node number (DID). The second symbol is the source node number (SID). The third symbol is the count of symbols in the rest of the message, excluding the final symbol. The fourth symbol is the Packet Sequence Number. The final symbol is a cyclic redundancy check generated from all of the previous packet symbols.

When a node is polled it may transmit a data packet to any other valid network node. The destination node will recognize the node number in the packet header and attempt to receive it. If the data packet is received intact and error free, the recipient node issues an ACK message within 800 microseconds. On receiving of the ACK message, the send-

ing node issues a Pass message, having completed the data packet transaction.

A data packet transmission error can result from data errors, inadequate buffer space in the receiver, or a destination node that does not exist. Any data packet error causes the packet to be ignored and no response to be generated.

The Packet Sequence Number protects against the reception of multiple copies of the same packet should an acknowledgement to not be properly received. This field contains a number that is one greater than the last number transmitted by a node to a node. A zero in this position causes the packet to always be accepted, for example when the proper sequence number is unknown. For example, the first packet sent from one node to another should use sequence number zero. This assures acceptance of the packet and also sets the receiver sequence number check to zero. Subsequent packets then use the next sequence number. The receiver thus must maintain seperate sequence numbers for each node that sends it a message. If the receiver cannot maintain such a list, it should ignore sequence numbers. Likewise, a transmitting device must retain seperate sequence numbers for all nodes to which it will transmit. If unable to do so, the transmitter should instead issue zero value sequence numbers to ensure packet acceptance.

Node Search Algorithm

The Node Search method fills a table with Serial Numbers of nodes located. Each subnetwork node is placed into the Node Search mode by a special system message. In this mode, all background processing stops.

When a node device receives a Bit Test (n) command, if it has not been de selected, it will test the (n)th bit of its hardware serial number. If the bit tested is a "1," this node will issue a response byte onto the network and set a response flag. If the bit is a zero, this node will perform no network transmission, and clear the response flag.

When a node device receives a Select Ones command, it examines the response flag and deselects itself if the flag is false.

When a node device receives a Select All command, it re-selects itself and will then respond to Bit Test (n) commands.

When a node device receives a Node Load command, it accepts the following byte as a new node ID and then validates that byte with the next byte that comes in, expecting it to be the complement of the node ID. If the new node ID checks out, this node device leaves the Node Search mode and waits for normal polling, ignoring all Search Node messages thereafter.

When a node device receives a Test All command, it transmits a signal on the network to indicate that it is still in the Search Node mode.

Logger PC and Workstation Applications Data Format

In use, the logger PC **100** typically runs an application that keeps track of TAGs and touch memories. For example, a typical log file contains 22-byte binary records as follows:

(TIM)	=	Time-of-day	4-Bytes
(01)	=	Constant Value (Serial # type code)	1-Byte
(CSN)	=	Collector (Resource) Serial Number	6-Bytes

-continued

(PPN)	=	Physical Port Number	1-Byte
(CAT)	=	Category Code	1-Byte
(EVT)	=	Event Code	1-Byte
(REG)	=	Touch Memory Registration Number	8-Bytes
			22-Bytes
The (REG) field is further defined as:			
(TYP)	=	Touch Memory Device Type	1-Byte
(RSN)	=	Device Serial Number	6-Bytes
(CRC)	=	Registration Num CRC Check Byte	1-Byte
			8-Bytes

To use a common database for touch ports and touch memory devices, the eight-byte (REG) field is interchangeable with the (01) (CSN) (PPN) field (also 8 bytes) to describe a unique Touch Port (MicroLan) location.

Category Codes

Because multiple applications programs may access the subnetwork, messages can be assigned to one or more categories depending on their function. Application programs then act on messages in one or more categories and ignore messages in other categories.

The category code is an eight bit binary value with each bit representing a category. The system administrator defines each category. When a resource (such as the touch collector **300**) is provided a mission, it is also provided a category for messages that it might receive or transmit. Likewise, an application is assigned one or more categories and then processes only the messages in those categories. When any system resource or application transmits a message with a specific category mask, that message is received and acted upon only by those resources or applications that have at least one matching category bit. An all-zero category value indicates a special case and should be ignored by all normal, missioned devices. An all-ones category value, as would be expected, is accepted by all devices.

Touch collectors **300** retain a category mask per-port, allowing ports on the same touch collector **300** to have different uses (categories) in a system.

Each application program is provided a category mask through an initialization data file. Each downchannel resource (collector) is provided a category code as a part of the process of port/sensor definition.

For example, the system administrator defines category **1** for touch memory reports, category **2** for IR tracking reports, category **3** for access control reports, category **4** for HVAC controls, and category **5** for security.

The touch collector **300** has four touch ports **308** at controlled doorways, which are missioned to be category **3** (access control), category **1** (touch tracking), and category **2** (IR tracking). Two of the touch collector **300** ports are connected to HVAC temperature sensors, so they are missioned as category **4**. Another group of ports are used for guard tour and other security applications, and so are in category **5**. The remaining ports are touch memory terminals within the facility and are category **1** and category **2**.

An access control application is programmed to respond to category **3** messages. An IR tracking system logger application responds to category **2** messages, a touch logger application responds to category **1**, and an HVAC control application responds to category **4** messages.

When a touch memory device 312 is inserted into a touch port 310, the message is issued as categories 1,2, and 3. The Access Control application then responds to the message and, perhaps, unlocks the door. Likewise, the touch tracking application logs the arrival and departure of the touch memory 312, and the IR tracking application logs a position report.

Temperature change on the HVAC sensing port, however, sends a message in only category 4, so only the HVAC control application responds and perhaps starts or stops a cooling or heating system.

Guard tour activity is missioned to perform category 5 and also category 2 for general tracking of the security staff. Guard tour reports might also include category 3 where the station is near an area that requires a controlled access entry by the guard on rounds.

Event Codes

Typical event code definitions are listed below. The return status code (RSC) for a given command is the same code as the command which instigated the response.

	Touch Memory (TMEX) Low Level Group:
00	TMEX: Setup
01	TMEX: Touch Reset
02	TMEX: Touch Byte
03	TMEX: Touch Bit
04	TMEX: First
05	TMEX: Next
06	TMEX: Access
07	TMEX: Romdata
08	TMEX: FirstAlarm
09	TMEX: NextAlarm
0A	TMEX: Read Packet
0B	TMEX: Write packet
0C	TMEX: Block I/O
0F	TMEX: Close
	Touch Memory (TMEX) File Group:
21	TMEX: Find First File
22	TMEX: Find Next File
23	TMEX: Open File
24	TMEX: Create File
25	TMEX: Close File
26	TMEX: Read File
27	TMEX: Write File
28	TMEX: Delete File
29	TMEX: Format Touch Memory
2A	TMEX: Set Attributes
	Missioned Touch Tracking-Group:
40	Touch Memory Contact (Includes CSN/PPN, REG, CAT)
41	Touch Memory Arrival (Includes CSN/PPN, REG, CAT)
42	Touch Memory Departure (Includes CSN/PPN, REG, CAT)
	Missioned Infrared Tracking Group:
A1	IR Tag Report (w/o coordinates)
A2	IR Tag Report (w/coordinates)
A3	Coordinate Read (by CSN/PPN where PPN = sensor mask)
A4	Coordinate Write (by CSN/PPN where PPN = sensor mask)
	System Control/Assignment Group:
F1	Read Mission (by CSN/PPN)
F2	Write Mission (by CSN/PPN, Includes spec, parms, cat)
F3	Down line Load Mode Control / Data Packet
FC	Resource Wakeup Message
FD	Departing Resource Report

-continued

FE	Arriving Resource Report
FF	System Error Reports

When an application receives a message in the appropriate category, it logs or otherwise acts on the data it contains. Some applications use the same packet formats. For example, a door access control application might be able to recognize Touch Memory Arrival messages and also IR Tracking Tag Report messages. Note that a unique location is a CSN/PPN in either system, as the IR method places the sensor "mask" (effective sensor number) in the PPN position even when coordinate reports are used.

System control Message Formats

System control messages are-common to all subnetwork resources. They are used to report subnetwork errors, perform program downloads and diagnostics, and for general network maintenance.

System messages are generally issued with a zero (override) sequence number.

System Message: DownLoad Control

The DownLoad Control message is used to start, process, and complete a download of program code to a resource. The (PPN) field is used to indicate the start of a download operation (00), a download data block (01), and the end of a download operation (02).

Download operations begin when the concentrator 104 delivers a directed DownLoad Start message (PPN=00) to a resource. The resource suspends all operations, invalidates its current loadable code, and waits for download data. During this time, all other messages are ignored. The DownLoad Start message is formed as follows:

(PPN)	=	1-Byte (=00)
(CAT)	=	1-Byte category (=0FFH)
(EVT)	=	1-Byte (= 0F3H)
(LEN)	=	1-Byte data length count = 0

To prevent an error from invoking a download start action, all the parameters are checked and must be as defined above.

Download data is issued in DownLoad Data messages, formatted as follows:

(PPN)	=	1-Byte (=01)
(CAT)	=	1-Byte category (=0FFH)
(EVT)	=	1-Byte (= 0F3H)
(LEN)	=	1-Byte data length count = (n)
(LAL)	=	1-Byte Load Address LSP
(LAH)	=	1-Byte Load Address MSP
(data)	=	(n-2) Data Bytes
(DCS)	=	DownLoad Check (Mod 256 Sum of all n data bytes, LAL, LAH)

When the download is completed, a final DownLoad End message is issued, formed as follows:

(PPN)	=	1-Byte (=02)
(CAT)	=	1-Byte category (=0FFH)
(EVT)	=	1-Byte (= 0F3H)

System Message: Resource Wakeup

The Wakeup system message is used by a device on power-up to report that it is present and active in the system.

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A system message can only be issued by operational downloaded program code, and is issued on completion of a download when the downloaded code is executed. For this reason, the Wakeup message is an indication of a successful download operation.

The WakeUp message also contains the device serial number, allowing the concentrator 104 to see if the device is new to the subnetwork and, if so, to invoke a renumbering of the network nodes.

(PPN)	=	1-Byte sensor mask (Always 0)
(CAT)	=	1-Byte category (always 0FFH)
(EVT)	=	1-Byte = 0FC(hex) event code
(LEN)	=	1-Byte data length count = 6
(RSN)	=	6-Byte Resource Serial Number

System Message: System Error Report

The Error Report system message is used when a device has sustained an error of sufficient magnitude that it must be known to the concentrator immediately. Error report messages contain a data field in which the first byte is an error code, defined as follows:

00	Undefined Error Conditions
1x	Subnetwork Communications Errors
2x	Download Progress Errors (data, sequence, etc.)
3x	Initialization Errors (RAM test, ROM test, hardware tests, etc.)
4x	Configuration Errors (user configuration)

Infrared Tracking System Message Formats

Messages used by the fixed-mission IR tracking Collectors may be unmapped types which contain coded location data, or mapped types which report tag locations in X,Y,Z terms.

The unmapped tag report message is formed as follows:

(PPN)	=	1-Byte sensor mask
(CAT)	=	1-Byte category (as missioned)
(EVT)	=	1-Byte = 0A1(hex) event code for un-mapped IR tag reports
(LEN)	=	1-Byte data length count = 4
(TAG)	=	3-Byte tag ID (LSB first)
(TST)	=	1 - Byte tag state (TCNT+S0+S1+M+B)

The mapped tag report message is formed as follows:

(PPN)	=	1-Byte sensor mask (included for non-mapped applications)
(CAT)	=	1-Byte category (as missioned)
(EVT)	=	1-Byte = 0A2(hex) event code for mapped IR tag reports
(LEN)	=	1-Byte data length count = 10
(TAG)	=	3-Byte tag ID (LSB first)
(TST)	=	1 - Byte tag state (TCNT+S0+S1+M+B)
(LCX)	=	2-Byte 'X' location coordinate
(LCY)	=	2-Byte 'Y' location coordinate
(LCZ)	=	2-Byte 'Z' location coordinate

Tag locations are mapped using a coordinate table stored in the Collector non-volatile RAM area. For each valid sensor mask combination, three 2-byte coordinates and a category byte are stored. (Translating IR collectors can have different categories for each sensor position or overlap combination.)

Touch Memory System Message Formats

Touch memory event logging (missioned functions) use a packet format as follows:

(PPN)	=	1-Byte Physical Port Number (1–24)
(CAT)	=	1-Byte category (as missioned)
(EVT)	=	1-Byte = 04x (hex) event code for Touch Reports (40,41,42)
(LEN)	=	1-Byte data length count = 8
(REG)	=	8-Byte Registration Number of device

Use of Subnetwork OIDs in a Tracking and Location System

To illustrate the operation of the tracking system using a network and subnetwork, two examples will be discussed. First, the system response to an IR TAG **328** or **330** coming into the presence of an IR sensor **332**, **334**, or **336** will be examined. Second, the presence of the touch memory **312** coming into contact with the touch port **310** will be examined.

Referring to FIG. **5**, first the IR sensor situation is analyzed. On system startup, before any stimuli from the IR TAGs **328** and **330** is received, the concentrator **104** first must establish communications with the various collectors and controllers **300**, **302**, **304**, and **306**. To do so, the concentrator **104** enters a node search mode, issuing a node search mode command. The various collectors and controllers **300–306** sequentially respond, and are assigned node numbers by the concentrator **104**. The concentrator **104** further receives each of the collector and controller **300–306** unique identifications uniquely identifying those nodes. On system startup, the logger PC **100** also must establish communication with the concentrator **104**. To facilitate this, the logger PC **100** first requests the next sequence number of the stimuli event from one of the various devices connected to the collectors and concentrators **300–306**. The logger PC **100** does so by issuing an SNMP Get command with its variable number set to zero, and preferably with its class number set to zero, such as "96.0.0.0". The variable number set to zero requests identification of the next stimuli sequence number that will be received from the concentrator **104**.

Further, the concentrator **104** can download status and firmware to the various collectors and controllers **300–306** using the SNMP indirect and load status variables, such as "96.0.1" and "96.0.3".

Once communication is established, the concentrator **104** polls each of the collectors and controllers **300–306** using invitation to transmit commands on the subnetwork. Each of these nodes then issues a pass command in response if it has not received a stimuli event from any of the various devices connected to that particular node. This continues until a stimuli event is returned.

Then an IR TAG, such as the IR TAG **328**, enters the proximity of the IR sensor. **322**, for example. At that point, the raw binary code is transmitted up to the IR collector **302**. This code contains the unique TAG identification, as well as TAG status, such as its battery strength, its motion status,

and the transmit sequence number. The IR collector **302** then has a stimuli event to report, so the next time the concentrator **104** polls the IR collector **302**, instead of responding with a pass message, the IR collector **302** transmits a data packet to the concentrator **104** including the node number assigned by the concentrator **104** to the IR collector **302**, as well as the data received from the IR TAG **328**.

The concentrator **104** then has a stimuli event to report, including the node that received the stimuli, the particular sensor connected to the node, as well as the identification and status of the IR TAG **328** transmitting that data. This stimuli event will be the next SNMP sequence number, such as 1.

The logger PC **100** will have previously issued a Get stimuli report message to the concentrator **104** requesting the number of the next stimuli using "96.0.0.0". The logger PC **100** will then have followed that Get command with a Get command requesting the next sequence number of stimuli event, i.e., "96.0.0.0.1". That will be the stimuli as transmitted by the IR TAG **328**. So, the concentrator **104** has a pending Get request for that particular sequence number, and transmits the data, including the particular node, the particular port connected to that node, as well as the unique identification of the IR TAG **328** and its status, onto the logger PC **100**. The logger. PC **100** then logs this stimuli event into a log file, which can be accessed using standard DLL commands by other workstations on the network.

Now, assume that the touch memory device **312** is placed into the touch port **310**. The messaging proceeds as with a transmission from the IR TAG **328**, with the additional status that the device has been placed into the touch port **310**. When the logger PC **100** receives this message, it may wish, for example, to buzz the piezoelectric sounder **412**. The logger PC **100** will have a map indicating that the touch port **310** is connected to a particular collector on a particular port. Therefore, it sends a Set message to the concentrator **104**, designating the RSN of the correct addressable transistor on the correct node and channel: "96.0.16.0.0.[RSN]". The concentrator **104** responds by sending a message to the collector **300**, instructing the collector **300** to send an activation message to the appropriate addressable transistor **418** in the touch port **310**. The touch collector **300** has a map of the unique identification of the addressable transistor **418** connected to its port one. It has generated this map on startup by scanning the addressable transistors connected to its various ports, and corresponding those ports with the various adjustable transistor connected. So, it then sends a pulse stream to the touch port **400** appropriate for activating the addressable transistor **418**. This sounds the piezoelectric sounder, and the touch collector **300** then sends a follow-up appropriate message for deactivating the addressable transistor **418**. The leads **408** and **410** are similarly activated through the addressable transistor **416**.

It will further be appreciated that the relay contacts **320** can be similarly activated through the addressable transistor **318**. Further, relays connected to the relay controller **304** are similarly activated by messages from the concentrator **104**.

Alternatively, the system could be implemented such that the touch collector **300** does not maintain a map of the unique identifications of each of the addressable transistors. Instead, this map can be maintained in the logger PC after an appropriate scanning of the various collectors and controllers **300–304** on the system. Then, instead of a set message directed at the touch collector **300** and a particular port on that touch collector, the logger PC **100** then issues a set command directed at the specific RSN on the adjustable transistor **418**. The concentrator **104** will then transmit a broadcast message to all of the collectors and controllers **300–306** on the subnetwork and each of those controllers would issue an appropriate data stream on all of its channels. Then, only the adjustable transistor **418** would respond, because the remainder of the addressable transistors had different unique identifications.

The foregoing disclosure and description of the invention are illustrative and explanatory thereof, and various changes in the size, shape, materials, components, circuit elements, wiring connections and contacts, as well as in the details of the illustrated circuitry and construction and method of operation may be made without departing from the spirit of the invention.

APP 1

```
/* snoidapi.h:
// This interface can be included by C or C++ code
*/
#ifdef_cplusplus
extern "C" {
#endif /*_cplusplus */
// Info in a Tag Report
typedef struct {
        unsigned char type;          // 0xa1 for tag report, no xyz
        long dcmID;                       // rightmost 4 bytes of 6 byte SSN
        unsigned int modID;          // leftmost 2 bytes of 6 byte SSN
        unsigned int tagID;
        unsigned char tcount;
        unsigned char tstate;
        unsigned char smask;
        int x;                            // if type=0xa2 xyz in feet
        int y;
        int z;
        char reserve[10];
} TagReport;
/* oidStr is a null terminated ascii string e.g. "1.2.3.4.5" */
// prototypes
void FAR PASCAL_export snPollOid( );
#define GetContinuous 0x01        // distribute data and repeat the get
#define GetSequential 0x02        // use special sequence sliding-window Algo
#define GetPolled          0x04   // primes the polling for an OID
int FAR PASCAL_export snGetOid( HWND userWindow, char far * oidStr,
```

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-continued

APP 1

```
                                        unsigned int getMods, unsigned char far * ipAddr );
int FAR PASCAL_export snNextOid( HWND userWindow, char far * oidStr,
                                        unsigned char far * ipAddr );
int FAR PASCAL_export snSetOid( HWND userWindow, char far * oidStr,
                                        unsigned int valType, unsigned int valLen, unsigned char far * val,
                                        unsigned char far * ipAddr ) ;
int FAR PASCAL_export snTrapOid( HWND userWindow, char far * oidStr,
                                        unsigned char far * ipAddr ) ;
/*
    all of these next routines return the length of the requested field from
    the pdu and store in the pointer the value
/*
#ifdef_SNOIDS
int FAR PASCAL_export snPduAck( PDU * pdu, unsigned int seqNo ) ;
int FAR PASCAL_export snWotOid( PDU * pdu, unsigned int seqNo, char far * oidStr ) ;
int FAR PASCAL_export snWotRawOid( PDU * pdu, unsigned int seqNo, unsigned char far * roid ) ;
int FAR PASCAL_export snWotValType( PDU * pdu, unsigned int seqNo ) ;
int FAR PASCAL_export snWotVal( PDU * pdu, unsigned int seqNo, unsigned char far * val ) ;
int FAR PASCAL_export snWotIPAddr( PDU * pdu, unsigned int seqNo, unsigned char far * ipAddr ) ;
int FAR PASCAL_export snWotPduType( PDU * pdu, unsigned int seqNo ) ;
int FAR PASCAL_export snWotErr( PDU * pdu, unsigned int seqNo ) ;
int FAR PASCAL_export snWotErrX( PDU * pdu, unsigned int seqNo ) ;
int FAR PASCAL_export snTagRep( PDU * pdu, unsigned int seqNo, TagReport far * tr, unsigned int which ) ;
int FAR PASCAL_export snStimulusReport( PDU * pdu, unsigned int seqNo,
    char far * channel,
    char far * collectorId,
    char far * ipAddr,
    char far * stimulusId,
    char far * receptorClass,
    char far * qualifiers,
    unsigned int which ) ;
#else
int FAR PASCAL_export snPduAck (LONG pdu, unsigned int seqNo) ;
int FAR PASCAL_export snWotOid( LONG pdu, unsigned int seqNo, char far * oidStr ) ;
int FAR PASCAL_export snWotRawOid( LONG pdu, unsigned int seqNo, unsigned char far * roid ) ;
int FAR PASCAL_export snWotValType( LONG pdu, unsigned int seqNo ) ;
int FAR PASCAL_export snWotVal( LONG pdu, unsigned int seqNo, unsigned char far * val ) ;
int FAR PASCAL_export snWotIPAddr( LONG pdu, unsigned int seqNo, unsigned char far * ipAddr ) ;
int FAR PASCAL_export snWotPduType( LONG pdu, unsigned int seqNo ) ;
int FAR PASCAL_export snWotErr( LONG pdu, unsigned int seqNo ) ;
int FAR PASCAL_export snWotErrX( LONG pdu, unsigned int seqNo ) ;
int FAR PASCAL_export snTagRep( LONG pdu, unsigned int seqNo, TagReport far * tr, unsigned int which ) ;
int FAR PASCAL_export snStimulusReport( LONG pdu, unsigned int seqNo,
    char far * channel,
    char far * collectorId,
    char far * ipAddr,
    char far * stimulusId,
    char far * receptorClass,
    char far * qualifiers,
    unsigned int which ) ;
#endif
/* snOIDtoDDD - converts an ASN1 encoded OID to a dot-deliminated decimal
    string */
unsigned int FAR PASCAL_export snOIDtoDDD ( unsigned char oidLen, unsigned char far * oid,
    unsigned char far * ddd )       ;
#define WM_SNOIDRESP           (WM_USER+1)
#define WM_SNOIDTRAP           (WM_USER+2)
#ifdef_cplusplus
}
#endif
```

What is claimed is:

1. An object location and tracking system for tracking infrared transmitters that transmit identifying codes, comprising:

a computer network for passing messages;

a computer connected to said network, said computer including means for sending and receiving messages over said computer network in a variable-based protocol that implements object identifier variables;

a plurality of infrared sensors for receiving transmitted identifying codes from the infrared transmitters, said plurality of infrared sensors providing signals containing the transmitted identifying codes; and

interface circuitry coupling said plurality of infrared sensors to said computer network, said interface circuitry including means for providing to said computer network object identifier variables in the variable-based protocol corresponding to the transmitted identifying codes received from said signals from said plurality of infrared sensors.

2. The object location and tracking system of claim 1, wherein the variable-based protocol that implements object identifier variables is Simple Network Management Protocol (SNMP).

3. The object location and tracking system of claim 2, wherein said interface circuitry appears on said computer

network as an SNMP server and wherein said computer appears on said computer network as an SNMP client.

4. The object location and tracking system of claim 1, wherein said interface circuitry further comprises:

a subnetwork for passing messages;

controller circuitry connected to said plurality of infrared sensors and connected to said subnetwork, said controller circuitry including means for sending messages containing the transmitted identifying codes over said subnetwork; and

concentrator circuitry connected to said subnetwork and connected to said computer network, said concentrator circuitry including means for providing to said computer network object identifier variables in the variable-based protocol in response to messages containing the transmitted identifying codes sent by said controller circuitry.

5. The object location and tracking system of claim 1 for further tracking the location of registered serial number devices providing unique identifying code, further comprising:

receptor circuitry with a physical receptor, said receptor circuitry providing a unique identifying signal representing the unique identifying code of a registered serial number device placed in said physical receptor;

said interface circuitry further coupling said receptor circuitry to said computer network, said interface circuitry further including means for providing to said computer network object identifier variables in the variable-based protocol corresponding to the unique identifying signal provided by said receptor circuitry.

6. The object location and tracking system of claim 5 for further providing responses to transmitted identifying codes, further comprising:

control circuitry coupled to said network, said control circuitry implementing object identifier variables and means for controlling external physical events responsive to said object identifier variables.

7. The object location and tracking system of claim 6, wherein said computer further comprises:

means for setting object identifier variables controlling the external physical events responsive to receiving object identifier variables indicating presence of a infrared transmitter.

8. The object location and tracking system of claim 1 for further providing responses to transmitted identifying codes, further comprising:

control circuitry coupled to said network, said control circuitry implementing object identifier variables and means for controlling external physical events responsive to said object identifier variables.

9. The object location and tracking system of claim 8, wherein said means for controlling external physical events further comprises:

an addressable transistor driving a light emitting diode.

10. The object location and tracking system of claim 8, wherein said means for controlling external physical events further comprises:

an addressable transistor driving a sounder.

11. The object location and tracking system of claim 8, wherein said means for controlling external physical events further comprises:

a relay controller.

12. The object location and tracking system of claim 8, wherein said computer further comprises:

means for setting object identifier variables controlling the external physical events responsive to receiving object identifier variables indicating presence of a infrared transmitter.

13. A method for tracking and locating objects in a system with a computer network, a computer connected to the computer network, infrared sensors, and interface circuitry connecting the computer network to the infrared sensors, the infrared sensors being adapted to receive unique identifying codes from infrared transmitters, comprising the steps of:

providing object identifier variables in the interface circuitry, said object identifier variables adapted for being communicated over the computer network in a variable based protocol;

receiving in one of the infrared sensors a transmission from one of the infrared transmitters containing a unique identifying code;

sending the received unique identifying code from the infrared sensor to the interface circuitry;

providing the unique identifying code in the interface circuitry to the computer network in association with an object identifier variable; and

receiving in the computer the unique identifying code from the network by accessing its associated object identifier variable.

14. The method of claim 13 further comprising the step of:

sending an inquiry for the object identifier variable from the computer to the interface circuitry over the network; and

wherein said step of providing the unique identifying code in the interface circuitry to the computer network does so responsive to said sending an inquiry.

15. The method of claim 13, wherein said object identifier variables are provided in SNMP format.

16. The method of claim 13 also for providing physical responses and the system also having an external device controller, further comprising the steps of:

sending a message from the computer to the external device controller, the message containing an object identifier variable associated with a channel of the external device controller instructing the external device controller to activate the channel, said message sent in response to said unique identifying code provided by the interface circuitry to the computer network;

activating in the external device controller the channel contained in the object identifier variable in response to receiving said message sent by the computer.

17. The method of claim 13, the system further including a physical receptor for a registered serial number device with unique identifying code coupled to the computer network by the interface circuitry, further comprising the steps of:

receiving the registered serial number device's unique identifying code in the physical receptor;

providing the registered serial number device's unique identifying code to the computer over the computer network in conjunction with an object identifier variable identifying the physical receptor.

18. A method for tracking and locating objects in a system with a computer network, a computer connected to the computer network, infrared sensors, and interface circuitry connecting the computer network to the infrared sensors, the infrared sensors being adapted to receive unique identifying codes from infrared transmitters, also for providing physical

responses and the system also having an external device controller, comprising the steps of:

receiving in one of the infrared sensors a transmission from one of the infrared transmitters containing a unique identifying code;

sending the received unique identifying code from the infrared sensor to the interface circuitry;

providing the unique identifying code in the interface circuitry to the computer network;

receiving in the computer the unique identifying code from the network;

sending a message from the computer to the external device controller, the message containing an identification of a channel of the external device controller instructing the external device controller to activate the channel, said message sent in response to said unique identifying code provided by the interface circuitry to the computer network; and

activating in the external device controller the channel identified in said sending a message step in response to receiving said message sent by the computer.

19. The object location and tracking system of claim 1, wherein the interface circuitry further includes components for coupling said plurality of sensors to said computer network, and further includes means for providing to said computer network object identifier variables in the variable-based protocol corresponding to status of and control of the components.

* * * * *